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WHAT WE DO NOT KNOW ABOUT RACE

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WE are, in this discussion, going to focus upon race and problems of race purely from a biological angle. The approach may be illustrated by an experience the writer had some dozen years ago. In 1930–31 it was his privilege to study in the Galton Laboratory of Applied Eugenics at London University. On the first day, as he ascended the stairs to a second-floor classroom, he saw on the landing-wall in front of him a huge illustration, an enlargement of a cartoon that had appeared in *Punch*. Two English country gentlemen were standing beside a blue-ribbon bull, and one gentleman said to the other, "We know about breeds in animals, but what about ourselves?" The theme of this discussion is, then: What about breeds in our biological selves? We shall discuss these selves not in individual, but in group terms. In a very real sense what we do not know about human biological groupings may become positive knowledge if it outlines future avenues of research. If we recognize a darkness we also recognize a need for light.

The *first* "don't" is simply this: we are not sure—at least we do not agree—what actually constitutes a biological race in man. In 1871 Charles Darwin, in "The Descent of Man," expressed the problems of racial classification quite clearly:

> Every naturalist who has had the misfortune to undertake the description of a group of highly varying organisms, has encountered cases . . . precisely like that of Man, and if of a cautious disposition he will end by uniting all the forms which graduate into one another, under a single species; for he will say to himself that he has no right to give names to objects which he can not define.

Darwin represents one extreme: there is but one race, the *human race*. One may study the literature on human racial classification and go to the other extreme, wherein no less than 150 species, each with sub-races, are postulated.

In 1735 Linnaeus, the great Swedish naturalist, gave Man the scientific name he to-day still bears—*Homo sapiens* (the "wise man"). Let us analyze ourselves biologically: an expanded cerebral cortex that makes of us a reasoning animal; a protracted period of infancy and childhood that enables us to be a learning animal; a facial skeleton reduced in size so that we have a physiognomy instead of a snout; a forelimb that is freed from locomotion so that a forepaw has become a hand; a spinal column, viscera, a pelvic girdle, and a hind limb, that are reasonably well adapted to an upright posture and bipedal locomotion. In this general morphological pattern all mankind is truly one: one genus, one species. In all important and major bodily details we are one—in brain, in peripheral nerves, in heart, in blood and blood vessels, in all

viscera, in muscles, and in skeletal architecture.

But there do exist differences which are, as it were, superimposed upon this basic ground-plan. There are differences in skin color, in eye color, in hair color and hair texture, in head shape, in nose and lip shape, and even in limb proportions. These differences are obvious, they are external, and we have recognized them for thousands of years. On the basis of skin color, principally, we subdivide *Homo sapiens* into three major groups: White, Yellow, Black. Scientifically we may designate these as *H. s. caucasoideus, H. s. mongoloideus, H. s. negroideus,* respectively.[1] Each of these groups—in practice we often call them "stocks"—is a sub-species, and each has certain distinctive morphological features which, taken singly, are not necessarily mutually exclusive, but which, taken in combination or complex, do tend to set the groups apart. Actually, this same general conclusion applies to sub-species in lower forms as well.

So far, so good. Now let us observe one of these stocks—the Caucasoids—in greater detail. Within this sub-species, in Europe, there are groups which, originally on a geographical basis, precipitate out as more or less recognizable entities: Northwest, Central, Southwest, Northeast, Southeast. To these types—and we here use a simplified terminology—have been applied the names Nordic, Alpine, Mediterranean, Baltic and Dinaric, respectively. They fall into place in our scheme as follows:

H. s.	*caucasoideus*	*nordicus*
" "	"	*alpinus*
" "	"	*mediterraneus*
" "	"	*balticus*[2]
" "	"	*dinaricus*[2]

In this stock break-down we come, finally, to the groups that the anthropologist generally terms race; they are, in taxonomic fact, sub-sub-species, or varieties. Do they exist to-day? The answer must be a qualified affirmative; that there may be local, isolated, probably highly inbred groups of Alpines, for example, in certain Swiss valleys. Similarly there may be small regional groups of the five Caucasoid varieties we have named. But there are no peoples or nations in Europe who are pure Nordics, pure Alpines, or pure anything else. In substance, there are *no pure races:* there are only populations in which two or more varieties are intermixed, and that intermixture began before the dawn of European history. Therefore, what we term races in Man are poorly defined, because they are not—as in races in lower forms—homogeneous; they are intermixed, hybridized, diffused. That is why one man says "no races," the other "many races." The first is appalled at the difficulty of disentangling intermingled varieties; the second holds that secondary or composite groups warrant racial status.

The problem of mixture above mentioned—of hybridization so that "racial purity" is non-existent—renders it impossible to ascribe genetic homogeneity to the races we have set up. Suppose we took ten persons classed as Nordics (five males, five females), and ten persons classed as Mediterraneans (five males, five females) and bred within each group: we could not guarantee, and we would not expect, that the offspring would be all Nordics and all Mediterraneans, respectively. In the Nordic × Nordic we might get some short, brunet, long-heads; in the Mediterranean × Mediterranean we might get some tall, blond, long-heads. About all we might reasonably expect is that the Nordic offspring would tend more to tall blondness, and the Mediterranean offspring to brunet shortness. In other words, the groups we call races are genetically heterogeneous; they include genes that are gen-

[1] Some anthropologists feel that these merit specific ranking.

[2] There is reason to believe that these were originally variant combinations of the three preceding, basic types.

eralized, and that are also shared more or less equally by one another.

Actually, how have we in practice set up a racial classification? The first method is that of *somatological inspection:* we look at a group and find that, on the average, they are short, slender, dark-complexioned, long-headed, wavy-haired, and their habitat is circum-Mediterranean; thus *H. s. caucasoideus mediterraneus* comes into being (Italians, Spanish, southern French, etc.). The second method is by *biometric analysis.* Here a certain portion of an entire group —a random sample—is measured and described precisely. If mathematical investigation shows that this sample (and hence the group) is statistically homogeneous and significantly different from all other groups, then the group under consideration is termed a race. "A biometrician's concept of race in man is derived primarily from the statistical study of samples. . . . His methods are essentially descriptive and they do not presuppose any particular theory of individual or racial heredity."[3] The end result of both of these methods is the *l'homme moyen,* or type, the hypothetical individual who represents the averages of all the individuals in the group (e.g., John Bull, Alphonse, Hans, Uncle Sam are caricatured types of an Englishman, a Frenchman, a German, an American).

In summary, our *first* "don't" recognizes that the groups we call human races are, taxonomically, sub-sub-species. As in all lower forms the differences which set these races apart—at such a taxonomic level—are not clear-cut and precisely defined. As far as Man is concerned, we focus upon a relatively few apparently stable characters and then accept them as having a definitive and diagnostic value. In doing this, however, we do not diverge radically from accepted zoological principles at sub-sub-specific levels for lower animal forms generally. At species level distinctions are quite clear; below that they are dim in the haze of variability.

The *second* "don't" is found in the fact that we are uncertain how stocks and races arose, i.e., when in human evolution they appeared and the mechanism involved in their emergence. We are pretty well satisfied that Man, as a primitive hominid, probably arose some five million years ago, more or less, as the result of a divergence from a generalized anthropoid form which gave rise to Man and the Anthropoids as we to-day know them. But that accounts for Man as Man—how about the White Man? The Yellow? The Black? Well, we are not really sure. There are suggestive finds, but nothing more. The first White Man may possibly be seen in Galley Hill man, resident in England some 400,000 years ago; the first Yellow Man is suggested by Weidenreich to date to Sinanthropus, the man of Peking, China, of about a million years ago; the first Black Man may date to Rhodesian man in Africa, 100,000(?) years ago—certainly he was present in southern Europe at Grimaldi, some 25,000 years ago. We repeat, we are not sure of the import of these finds in terms of the time-appearance of stocks. Two things must be borne in mind: first, the finds are random and inconclusive because we do not have sufficient numbers to know range of variation; second, the characters commonly diagnostic of stock or race are those of soft parts not preserved in the fossil record.

If stocks, or sub-species, be of doubtful origin, how about races, or varieties? Here we are more in the dark than ever. We can answer only that Mediterranean-type crania are found well defined by the opening of the Neolithic, about 10,000–15,000 years ago; Nordic-type crania are reported in the Swedish Neolithic. The time element in stock and race emergence is approximate, nothing more.

Now that we have considered when they arose, let us take up how they arose.

[3] G. M. Morant, in "Race and Culture," p. 24, 1934. Royal Anthropol. Inst., London.

One of the most intriguing theories is that of Sir Arthur Keith,[4] who feels that the endocrines may have played a role: "The transformation of man and ape . . . is determined by a common growth-controlling mechanism which is residual in a system of small but complex glandular organs." As Keith surveys the role of the pituitary in acromegaly, the thyroid in achondroplasia, the adrenals in pigmentation, the gonads in secondary sex characters, he sees analogies with certain statural, osteologic, cranio-facial, skin conditions in the stocks of mankind; e.g., the big-boned, rugged-skulled Caucasoid shows a possible pituitary dominance; the flat-faced Mongoloid shows a possible thyroid dominance; the dark-skinned Negroid shows a possible adrenal dominance.[5] Keith offers these endocrine associations more as suggestions than as absolute statements. They undoubtedly exist as factors, but to-day we recognize the endocrines as so complex, so interrelated, that any statement of uniglandular dominance must be taken with tremendous reserve. The exact role of the endocrines in human evolution and in the appearance of stocks and of races is in the realm of conjecture.

In our present knowledge of human evolution we assume that sometime, somewhere, there existed a generalized protohuman or hominid species that had, potentially at least, all of the morphological characters found to-day in all of mankind. This species must have been genetically fairly homogeneous, though probably inherently variable.

From this species there arose through mutation, recombination, selection, migration and isolation, the stocks and races as we now recognize them.

The *third* "don't" resides in the inadequacy of our knowledge concerning heredity in Man. Specifically, we do not know the precise mechanism whereby traits diagnostic of stock and race are transmitted.

One of the most obvious methods employed by the physical anthropologist in studying human heredity is to analyze the effects of race mixture.[6] Here it is assumed that the traits that "show up" or persist in a cross are "dominant." For example, when a long-head is crossed with a broad- or short-head it is apparently the broadness or shortness that dominates; similarly, nasal breadth dominates over nasal narrowness, lip thickness over lip thinness, and so on. But all this is not genotypic (genetic constitution) it is phenotypic (physical appearance). We do not know the exact genetic pattern involved; we know, for the most part, only what the end-result "looks like." Moreover, we are observing the operation of only a dozen or so pairs of thousands of pairs of genes in Man. It is this dozen or so for hair, eyes, nose, lips, skin, and a few other traits that we rely upon for stock and racial diagnosis; all the others are presumably constant for all groups.

Strandskov has given us an excellent summary of known gene distribution in Man.[7] Color blindness is a sex-linked recessive, with gene (*cb*) on the X-chromosome; color blindness is present when normal color vision (*Cb*) absent. Ability to taste the chemical phenyl thiocarbamide is an autosomal recessive with (*T*) for tasting, (*t*) for non-tasting. In the A–B blood groups we find inheritance by triple allelomorphs, as follows:

Blood group	*Gene combination*
AB	I^A I^B
A	I^A I^A or I^Ai
B	I^B I^B or I^Bi
O	ii

[4] Keith, A., "The differentiation of Mankind into racial types." *Ann. Rep. Smith. Inst.*, pp. 443–53. Wash., D. C. 1921.

[5] About 1775 John Hunter concluded that the original skin color of Man was black, and in 1921 Keith reaffirmed that statement.

[6] T. W. Todd, "Entrenched Negro physical features." *Human Biology*, 1 (1): 57–69. 1929; W. M. Krogman, "The inheritance of non-pathological physical traits in Man." *Eugenical News* 21 (6): 139–146. Nov.–Dec., 1936.

[7] H. H. Strandskov, "The distribution of human genes," SCI. MON., 52: 203–215, March, 1941; "The genetics of human population," *Am. Nat.*, 76: 156–164, 1942.

In the M–N blood groups we find the following:

Blood group	*Gene combination*	
MM	A^m	A^m
MN	A^m	A^n
NN	A^n	A^n

Biologically the knowledge of these few genetic patterns is important because the mechanism is identical for all human beings; the inherited traits cut straight across stock and race; e.g., *all* blood groups and their genes are found in Whites, Yellows and Blacks, though in varying percentage combinations. It is possible that these combinations may have some value in racial distinction, just as does skin color, etc., but as far as transfusibility is concerned (allowing for blood groups) all human blood is alike.[8]

We are certain that physical characters diagnostic of race and stock are hereditary: they arose genetically, via mutations and subsequent isolation; they have been perpetuated genetically in varying combinations. We know, for example, that there is an average of "one mutation for every 50,000 individuals per generation" (Strandskov), and that most of these mutations are of indifferent or even negative survival value. The few that are positive are transmitted and over a long period of time have entered into complexes and combinations which differ from stock to stock, and within stocks from sub-type to sub-type, from variety to variety. We are slowly but surely learning the genetics of Mankind in terms of his many physical-type variants.

A *fourth* "don't" is really a corollary of the third, namely, we realize that discrete traits have a hereditary basis, but we are still not sure which of these traits are relatively stable and which are easily modifiable, so that the first set is useful in classification, the second extremely limited in use.

In studying problems of racial analysis Hooton[9] has outlined three categories of physical traits in Man: those that are non-adaptive, those that possess an acquired stability, and those that are easily modified. We may summarize these three categories as follows:

> There are certain features which appear to act as heritable entities, either as unit characters or with multiple factors. These comprise in general hair-color and eye-color, form of hair, eyefold, nose, lips, ear, incisor teeth and vertebral border of scapula, head breadth, face length, chin prominence and prognathism, and limb proportions, including intra-membral, inter-membral and trunk-limb ratios. These physical characters are non-adaptive, stable, fixed, and may quite reasonably form the basis of the assessment of racial distinctions. Furthermore, certain combinations of these traits, varying within natural boundaries, result in the establishment of subgroups within each major classification.
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> We come now to several traits which have in the course of time been functionally modified and by selection have become more or less stabilized; at least their variability is of intra-racial rather than inter-racial magnitude. Here we may include skin color, shape, size, and proportion of the malars and the palatal arch, head height and brain volume, and possibly certain calcaneo-gastrocnemic relationships. The list is small and its import uncertain; the farther we go in our study of individual growth patterns and their probable relation to presumed racial criteria the more we must allow for modifiability. It may be that the stability is spurious, merely a transitory phase in the creation of an ultimate pattern dictated by constitutional vicissitudes.
>
> Finally, there are a number of bodily features so directly susceptible to health, diet and food habits, climatic factors, gait, exercise, occupation and other miscellaneous influences as to render them useless as racial criteria. Here must be mentioned height, weight, thoracic dimensions and proportions, nasal proportions, facial width, proportions of forearm and hand, relationship of vertebral column and pelvic girdle, and shaft proportions of femur and tibia.
>
> It may be finally emphasized that we must, in problems of racial interpretation, pay general attention to the sum total of all bodily traits, but specific and critical attention to the non-adaptive bodily characters, for these are transmitted regardless of the multifarious and complex extraneous factors of the environment. All things equal, it is not one, not two, but the

[8] It is implied in the phrases "blood-relation" or "blood will tell" that somehow blood is a carrier of familial relationship. The blood group is itself inherited, but blood, per se, is not a vehicle of genetic transmission.

[9] E. A. Hooton, "Methods of racial analysis." *Science*, 53: 75–81. 1926.

majority or all of the traits, in unique combination, which really constitute racial or group differences. But until we know more of the heredity of the several traits, of the effect of the growth-pattern upon these traits, we can not truly assess them in terms of non-adaptivity, acquired stability, or modifiability.[10]

For the last thirty years we have had reason to doubt the stability of certain morphological features, as in the cephalic index studies of Boas and his students, wherein significant generational differences were observed when foreign-born parents and American-born Jews and Sicilians were studied. In recent years Shapiro[11] has suggested that instability is characteristic of a majority of Man's physical racial traits. He studied three generations: (1) "sedentes," native parents born and still resident in Japan; (2) Japanese-born (of these parents) who migrated to Hawaii in their late 'teens; (3) Hawaiian-born children of these immigrants. The anthropometric battery comprised twenty-eight measurements with twenty-one derived indices and twenty-two observations. When the first two generations were compared it was found that they differed significantly in all traits measured and observed as follows: male, 72.4 per cent.; female, 67.9 per cent. As between the second and third generations the corresponding differences were 55.2 per cent. and 42.9 per cent., respectively. These differences are progressive from sedentes, to immigrants, to Hawaiian-born, but whereas between sedentes and immigrants disproportionate changes occur, between immigrants and Hawaiian-born proportionate changes are the rule. The progression is apparently a real one, relatively unaffected by age-changes or changes in occupational status. The causes of the changes are twofold: the immigrants probably constituted a subgroup of the sedentes population from which they were drawn; the new environment (of Hawaii) provided a stimulus toward change and some inbreeding intensified the variant exemplified by the immigrants. But the changes are, of course, limited in extent—the Japanese in Hawaii, as long as they marry within their own group, will always be Japanese; biologically they will not, can not, become Hawaiians, even though there might be some environmental convergence.

We now regard human races as much more plastic than we formerly did. But our concept of plasticity is basically a genetic one. There are a multitude of genes which encompass the entire range of human physical characters. Plasticity resides principally in recombinations of these characters. Recently Mills[12] has shown that there is another phase to this plasticity, an environment (diatetic) aspect. He found that vitamin B requirements (thiamin, pantothenic acid, and pyroxidene at least) are much higher in the tropic than in a temperate zone, and that growth and development are inhibited by inadequate B intake under tropical living conditions. Here is an example where growth-pattern and hence adult configuration (taken as a racial criterion) is modifiable by the food environment. We are just beginning to learn how a temperate-zone White man may possibly adjust to a subtropical or tropical habitat, but for one fact we know there are 100 questions that are still to be answered.

The *fifth* "don't" is found in the functional aspects of Man: we know little about the physiology of race-types. We have studied racial metabolism, pulse-rate, respiration-rate, and so on, but these analyses are not so much tests of race-groups *per se* as reflections of conditions under which they live. There is no reason, really, to assume difference in kind, rather only differences in degree. If we relate body-type to body-function then distinct group differences can not be

[10] W. M. Krogman, *op. cit.*, pp. 144–145.

[11] H. L. Shapiro (with F. S. Hulse), "Migration and environment." Oxford U. Press, N. Y. 1939.

[12] C. A. Mills, "Climatic effects on growth and development, with particular reference to the effects of tropical residence." *Amer. Anthropol.*, 44: 1–13. 1942.

expected, for body-type cuts across stock- and race-lines.[13]

There is another phase of the functional problem which requires classification, viz., so-called "racial immunities" and "racial susceptibilities." For example, the peoples of North Europe are said to be prone to whooping cough, resistant to goiter and cretinism; the peoples of Central Europe fall prey to goiter and cretinism, but withstand pulmonary diseases; the American Negro succumbs to tuberculosis, diseases of heart, lungs and kidneys, and more successfully combats malaria, yellow fever, measles, scarlet fever and diphtheria.[14] Are these really *racial* differences? Probably not. The answer is more likely to be found in problems of relative isolation and exposure, and most certainly in considerations of socio-economic standards. There are, so far as we know, no genetico-racial biological differences in the organs which will conduce to, or inhibit, organic breakdown under the onslaught of disease. The problem, however, is still one to be explored.

The *sixth* and final "don't" is that we do not know of any characteristics, either biological or psychological, that in a given race-cross are superior or inferior. On the biological side there may be one exception, viz., the sickle-shaped erythrocyte which is an autosomal dominant trait (Si) found only among Negroes, to the extent of 4 per cent.

Much is being made these days of "race superiority" and "race inferiority." In words of one syllable *there is no such thing.*[15] One hears of the woodsman who, on a crowded city street, heard a cricket; he can be matched by the mechanic who in the turmoil of a machine-shop hears a bearing-knock in an engine four rows removed. Again, there is the savage whose keen eye sees vast distances or detects a faintly-trodden blade of grass; he can be matched by the scientist who under the microscope sees a new world in a drop of water. The ear and eye are common human possessions as far as morphology is concerned—it is the degree of their training that differs. This type of reasoning can be applied to any phase of Man's activities: how he learns and how much he learns is dependent upon his cerebrum and upon the cultural framework within which he learns; the cerebrum is the constant factor, the cultural framework, the variable. The same holds true for "intelligence," however it may be defined and assessed. We repeat that biological superiority and inferiority in the stocks and races of man do not exist, and that biologically there is no valid bar to stock- and race-mixture. The first generation hybrids are not biologically inferior—it is Society and not Nature that stamps the brand of undesirability.

In recent years German anthropologists have, as we know, advanced preposterous claims of Nordic or "Aryan" superiority (*Das Herrenvolk*). Such claims have no basis in fact. They have also claimed that widespread race-crossing ("race bastardization") will have a dysgenic effect ("gene chaos"), leading to various bodily abnormalities and asymmetries. This, too, is far more fanciful than real, though Fleming,[16] an English anthropologist, has found some slight evidence of dento-facial disharmonies in Negro-White hybrids crossed with Negro-Chinese and Chinese-White hybrids. But this evidence is not conclusive, for there is no guarantee that growth inadequacies rather than genes

[13] F. Weidenreich, "Rasse und Körperbau." Springer, Berlin, 1927.

[14] A. Hrdlička, "Immunity as the chief task of future medicine." *Lit. Digest.* Dec. 9, 1933 (see p. 14); see also J. H. Lewis, "The biology of the Negro." U. of Chicago Press. 1942.

[15] Otto Klineberg, "Race differences." Harpers, N. Y. 1935. W. M. Krogman, "Is there a physical basis for race superiority?" Sci. Mon., 51: 428–434, 1940; M. F. Ashley Montagu, "Problems and methods relating to the study of race. *Psychiatry,* 3 (4): 493–506. 1940.

[16] R. M. Fleming, "Physical heredity in human hybrids." *Annals Eugen.,* 9: 55–81. 1939.

are to blame, i.e., that malnourishment has not modified a genetic pattern. As matters now stand the crossing between sub-species or stocks is socially so unacceptable that only lower social strata are involved. It is precisely here that environmental impact and modification—in terms of insufficient and incorrect foods, improper hygiene, health hazards—are at their maximum. We have no adequate basis, therefore, for a true assessment and interpretation of the solely biological effects of stock-crossing. As far as we know the genetics of stocks and races, we need not, *a priori*, expect any biological maladjustment.

This discussion has been pretty much on the negative side—a sort of "hit parade" of scientific uncertainty with respect to race biology: we are not agreed what a race is, we are not sure when and how races arose; we do not know the precise hereditary mechanism in race; we are not sure which physical traits in race are stable, which modifiable: we do not know physiological and immunological features of race-groups; we can not assess race in terms of superiority and inferiority. In very truth we know little about the bio-genetical aspects of race.

Despite the foregoing avowal of inadequate knowledge we venture to present a definition of race that is sufficiently generalized to include the variables of physical type, heredity, environment and habitat:

> A race is a sub-group of peoples possessing a definite combination of physical characters, of genetic origin; this combination serves, in varying degree, to distinguish the sub-group from other sub-groups of mankind, and the combination is transmitted in descent, providing all conditions which originally gave rise to the definite combination remain relatively unaltered; as a rule the sub-group inhabits, or did inhabit, a more or less restricted geographical region.

Certainly the physical anthropologist is not so dogmatic about the clarity of distinction between racial groups as he once was. Indeed, there are those who would deny the existence of human races, and who advocate dropping the term entirely. If the term *race* is purely genetic, and if we do not know the genetic make-up (the genotype) of a presumed race-group, then it follows that we can not define the group genetically, and therefore it does not exist as a homogeneous genetic entity. This argument, as the present writer sees it, while biological on the face of it, stems more from a cultural misinterpretation of the term ("racism"), wherein race and nationalism are confused, than from considerations of presumedly diagnostic morphological characters.

There do exist certain groups which may be put into categories; i.e., there are groups which tend to precipitate out when defined by a certain physical trait-complex. The trouble resides in the fact that the trait-complex has been too rigidly defined, with too little allowance made for variability. The physical anthropologist freely admits that his classification has been based on the phenotype—the few external features used in diagnosis. We are prepared to reclassify upon the basis of the genotype—the basic genetic constituency. In both instances we will have groups called *races*: in the first instance—the present-day method—groups are classified by *what they look like* physically; in the second instance—the emerging bio-genetic method—groups will be classified by *what they are* genetically.

The term race as we use it today is a recognition that group differences do in fact exist. It does not imply, scientifically and biologically, a homogeneity such as demanded by geneticists. When our knowledge of human heredity enables us to classify the peoples of the world genotypically we will gladly accept that classification—we will substitute it for the one we now have. Until then, and with full and complete recognition of all of its many inadequacies, we will use the system at hand.

WINDS OF THE UNITED STATES

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ALTHOUGH the winds, aside from tornadoes and hurricanes, are often taken for granted, and are of less popular interest than are warmth, cold, rain, snow, and drought, wind directions and velocity are major causes of the variations in temperature and moisture. Indeed, this summary of the winds logically should have preceded the discussion of regional contrasts in the United States of temperature and precipitation presented in the preceding articles of this series (SCIENTIFIC MONTHLY, September, November, 1942, April, 1943.)

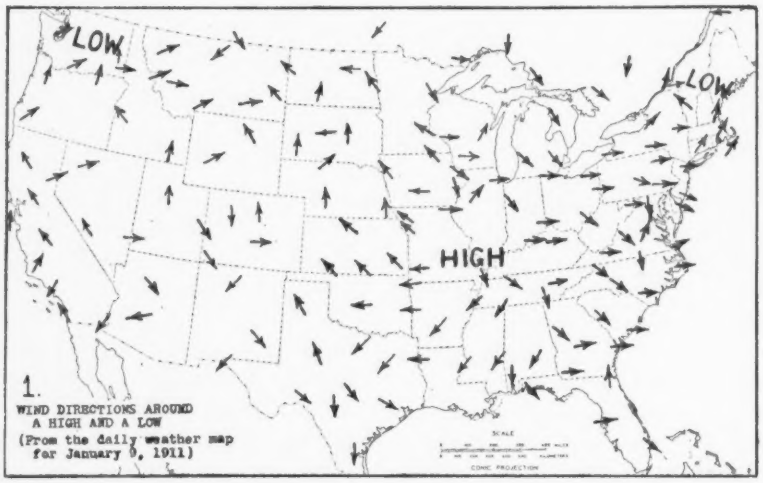
Winds of seven great types occur in the United States, although most of those we feel belong to one type. This common type is the winds which blow spirally out from the eastward moving masses or areas of relatively high air pressure called Highs, or which blow spirally into similarly moving areas of relatively low air pressure, known as Lows. As the Highs and Lows move across the country, the spiralling winds which they induce come, for any particular observer, successively from various directions. When the center of the High is to the west of the observer, northwesterly winds prevail; when its center passes over, a calm prevails for a time, followed by southeasterly winds. As a Low passes from due west, the wind directions change from south to north. If the centers of the High or Low pass to the north or south of the observer, somewhat different wind changes occur.

The wind directions reported by the Weather Bureau observers on a recent winter day are shown in Map 1, which is a copy of part of a daily weather map. On that particular day there was a large High near the center of the country and Lows in the northeast and northwest corners. The next day different wind conditions occurred, as the High moved to the Atlantic coast and the northwestern Low moved over Dakota.

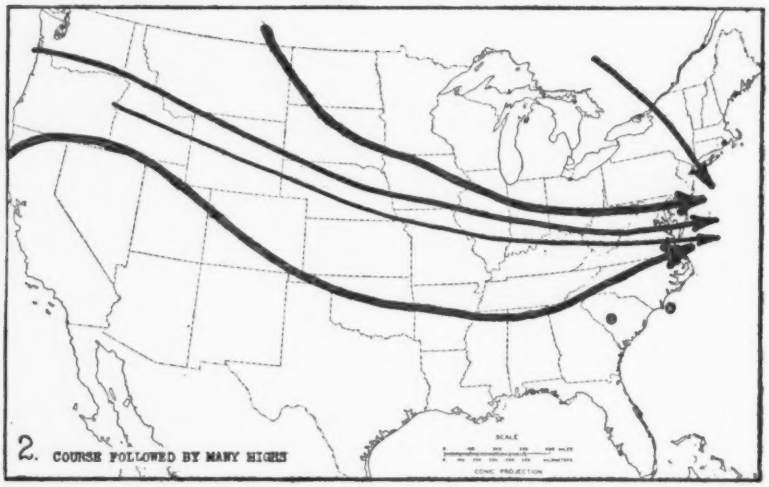
The Highs and Lows move eastward, but usually not due east for a great distance. Instead they often move southeast or northeast. The "paths" followed by many Lows and Highs are shown in the second and third maps. The lines which are exceptionally heavy represent roughly courses along which relatively many of these cyclonic disturbances travel. These maps are based on official Weather Bureau ones as to the courses followed, but the relative frequency of Highs and Lows along each course is partly based on studies by Van Cleef.

Maps 2 and 3 show that, on the average, the Lows move somewhat northward in crossing the United States, while the Highs move into lower latitudes. Indeed many Highs move rather rapidly southeastward from Western Canada, occasionally bringing cold weather in winter as far south as the Gulf coast.

The courses followed by Highs and Lows depend upon three chief influences. Their general eastward movement is due to the Westerlies, which prevail overhead most of the time in the United States, pushing the cyclonic masses eastward, or east-north-east. That the Highs move, in general, east-southeast instead of east-northeast, shows that the prevailing Westerlies (which blow from the west-southwest) are only one of the great influences affecting the course followed by the Highs and Lows. A second influence is that, as the result of the continual blowing of the Westerlies, air



1. WIND DIRECTIONS AROUND A HIGH AND A LOW (From the daily weather map for January 9, 1911)

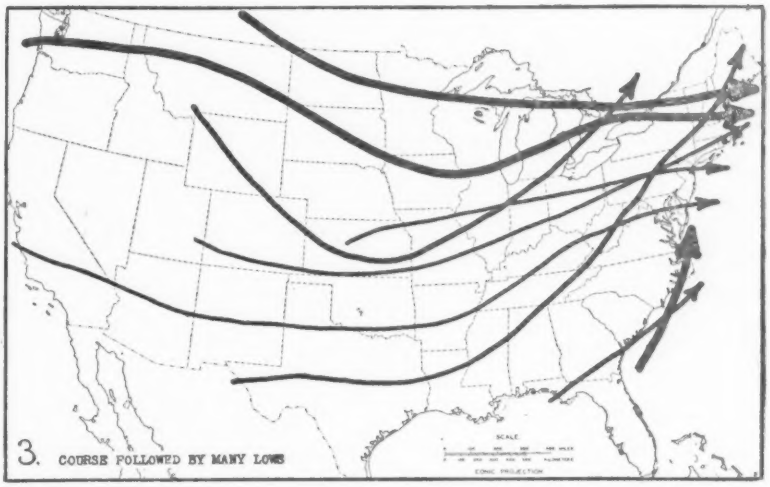


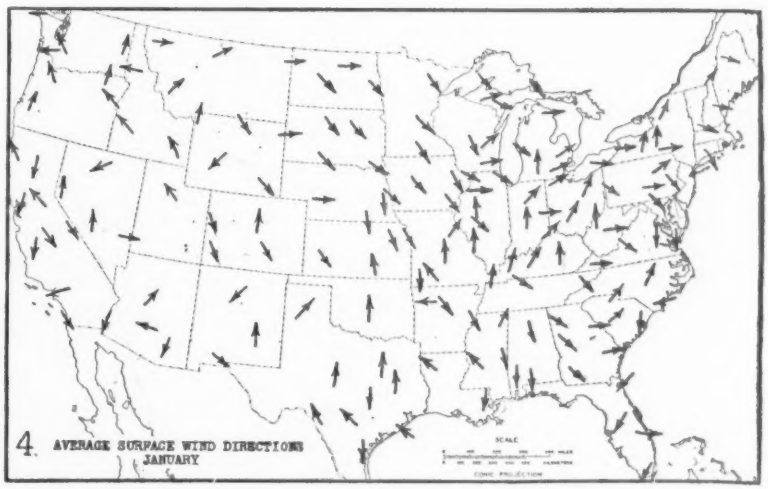
2. COURSE FOLLOWED BY MANY HIGHS

piles up in polar and subpolar latitudes. From time to time some of this air must return to lower latitudes or else finally much of the air would accumulate near the Poles. Our Highs are masses of subpolar air which have broken away and are moving east-southeastward across the United States.

A third influence which affects the courses followed by the Highs and Lows is air pressure conditions prevailing at the time in surrounding areas. The relatively high pressures which develop in summer time over much of the oceans in middle latitudes, and over much of the land in winter time, appreciably affect wind directions.

Maps 4 and 5 show the average or net wind directions in the lower air. They are copies of the Weather Bureau maps in the "Atlas of American Agriculture" by J. B. Kincer. Although each part of the country has winds from almost all directions, with such a rapid succession of changes that most people do not realize that one direction is more common than another, nevertheless these maps show distinct trends. During July, southerly winds prevail in most of the East, while in much of the West, northerly winds are





common. Conversely in winter, northerly winds are most common in the East and southerly winds in the West. Thus the average directions of the winds are an outward clockwise spiral in winter and in inward counterclockwise spiral in summer. This is the same way they blow out from a High and into a Low (Map 1). The continent thus, on the average, has relatively high pressure in winter and relatively low pressure in summer.

The tendency for the air to blow from relatively cool water bodies toward the warm land illustrated by Map 5 is much more strongly illustrated by the land and sea breezes, the third chief type of wind in the United States. Such winds are restricted to coastal areas and to times when the land is relatively hot. Lake breezes are often strong in hot weather on the southern and eastern shores of the Great Lakes, and are characteristic in summer along the Atlantic and Gulf coasts, and to a lesser extent on the Pacific coast. Land breezes, toward the water body, are just as frequent, but are less noticed, as they occur at night or in the early morning when the land is cooler than the water.

Map 6 shows the average velocity of the wind, miles per hour. It is a shaded copy of a colored map by Kincer in the

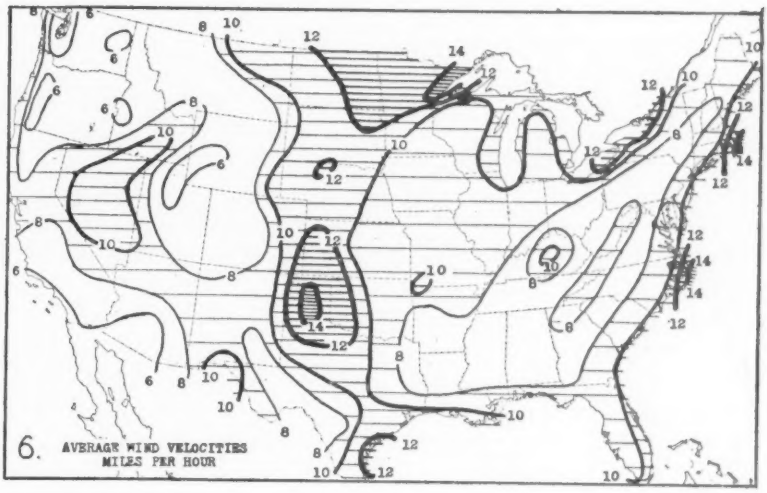
"Atlas of American Agriculture." It reveals that the average velocity is relatively great along the immediate Atlantic coast, in the Great Plains, and bordering the Great Lakes. In these areas the average velocity, approximately 12 miles per hour, is about 50 per cent. greater than in much of the East or West. The higher average velocity along the coast and on the Great Lakes is partly due to the less surface friction there. The smooth grassy Great Plains are relatively windy partly for the same reason. The low average wind velocities in much of the West are partly associated with the protected valley situation of most of the Weather Bureau instruments which measure the velocity. Mountain tops there usually have considerable wind.

The higher velocity on the coasts is partly due to the presence during part of the year of land and sea breezes. The higher average velocity in the Great Plains is partly due to the eastward slope of that area. Wind, like water, tends to flow down slopes.

The relatively low average velocity in the extreme southwestern part of the country is partly due to the fact that during midsummer that area is under the influence of the high pressure subtropical calm belt. That calm belt affects the Southeast less notably partly because thunderstorms are there more common.

Mountain-Valley Breezes

The fourth main type of wind in the United States is the so-called mountain and valley wind or breeze. These are local winds of little or no significance on level land. In hilly or mountainous areas, however, they often are of appreciable importance. Cool breezes often blow down the valleys at night, sometimes commencing soon after sundown. During the day, on the other hand, the normal breeze direction is up the valley. These changes are due to differences in the rate of heating and cooling associated with the topography. Hillsides upon which the early morning sun shines heat up much sooner than do the lowlands, which perhaps are still in the shade, and which often contain much more dew or frost which must be evaporated before the overlying air can become warm. When the hilltop or upper hillsides become relatively warm, a slight rarification of air occurs which results in a breeze in that direction. Conversely at night, the hilltops and shaded slopes cool more rapidly than the nearby lowlands, with their thicker blanket of air. The



cold air, being relatively heavy, drains down the valley, sometimes in restricted situations, forming quite a strong breeze.

A special kind of mountain wind is the foehn, or chinook, which occasionally is prominent in winter and spring on the eastern foothills of the Rocky Mountains, and on the leeward sides of various other ranges. Foehn winds are modified cyclonic winds rather than purely local winds, such as the breezes discussed in the previous paragraph, but their modification is due to the mountains and hence they are often called mountain winds. When cyclonic winds ascend a mountain range swiftly enough to have a considerable share of their moisture condensed by the cooling the ascent causes, the first big step in the formation of a hot, dry chinook has occurred. The clouds formed from the condensed moisture, together with the latent heat liberated by the condensation of moisture, interfere with the amount of cooling which the ascent should cause. Hence the air commences its descent on the leeward side of the mountain warmer than its altitude justifies. As it descends rapidly, it is warmed by compression and is rendered relatively dry, and hence cloudless. The sunshine associated with the cloudless sky facilitates further heating. Sometimes a chinook reaches the foothills twenty or even forty degrees warmer than the surface, causing a rapid evaporation or melting of the snow, and a sudden rise of temperature.

Chinook winds increase the utility of the western Great Plains for stock-raising, as their frequent removal of the snow cover facilitates winter grazing. By removing the snow and drying the soil, the chinooks also often permit spring wheat to be sown earlier than in areas beyond their influence. Early sowing is advantageous for spring grains partly because the more plant growth that has occurred before the hot and sometimes dry summer arrives the better.

The beneficial influence of the cool breezes which commonly blow down the valleys of rugged regions in hot weather are best illustrated in the tropics. In Honolulu, for example, building sites at the lower end of mountain canyons are far more valuable than nearby sites which are not bathed by cool valley breezes at night. Many sites in the eastern United States are appreciably affected, however, by such breezes. The writer recalls with gratitude the cooling evening zephyrs which regularly blew in hot weather down a valley which crosses the Cornell University campus, which is

on a bench far above one of the Finger Lakes. Several faculty homes are so situated as to benefit from this breeze.

Convectional Winds

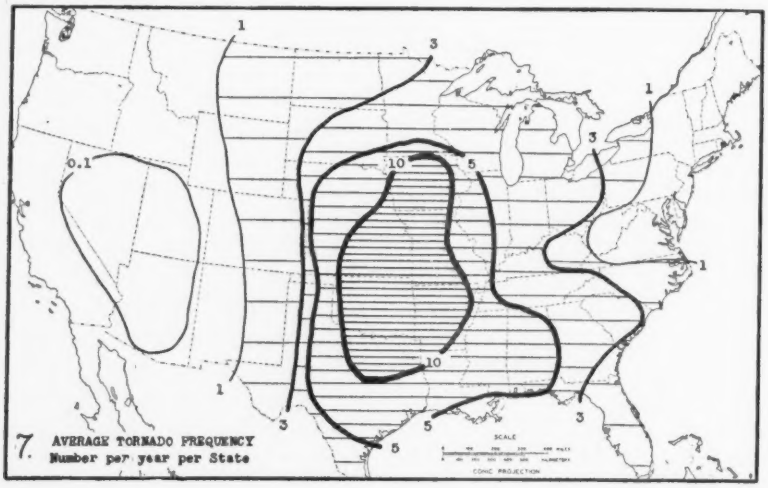
The fifth important kind of wind in the United States is the convectional. The most prominent convectional winds are associated with thunderstorms, but lesser ones cause much of our cloudiness, and convectional eddies cause dust whirlwinds. The conspicuous type of thunderstorm wind is a blast of cool air which often attains gale velocity, the thunderstorm squall. The updraft of warm air which makes the thunderhead grow now sometimes strongly affects airplanes, airships and gliders.

Convectional winds develop when the lower air, next to the ground, is much warmer than that not far above. Hence in the United States they are most common in summer. In the Southwest, however, thunderstorms, and also the convection-formed cumulus cloud, are common in autumn and spring, and are not lacking in winter. A map showing the annual frequency of thunderstorms is given in the November article of this series, Map 8, p. 451. It shows that in much of the Southeast thunderstorms occur on 60–80 days a year, two or three times as often as in most of the North. In the West, thunderstorms occur rarely near the Pacific coast, about ten days a year some 300 miles east of the Pacific, but on some fifty days a year in the central and southern Rocky Mountains.

Thunderstorm squall winds cause property losses of nearly ten million dollars a year, on the average, in the United States.

Tornadoes

Tornadoes, violent whirling winds, often incorrectly called cyclones, occur frequently in the United States and at least occasionally in much of the rest of the world. In the approximately 2,800 tornadoes recorded by the Weather Bureau in the United States during the twenty years 1916–1935, 5,224 people were killed and property losses in excess of $230,000,000 were sustained. Losses in excess of $100,000 were caused by 375 of these tornadoes; losses in excess of $1,000,000, by thirty. Three caused reported property losses of $24–43 millions each. One of these three and two others killed from 103 to 689 people. The worst was that of May, 1925, in southern Illinois.

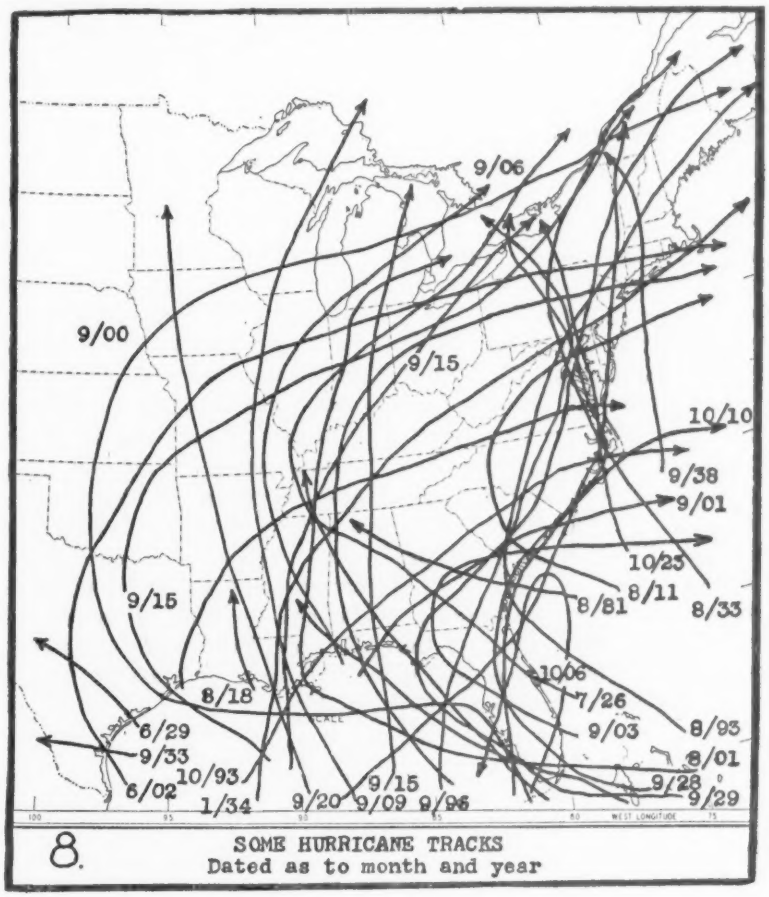


7. AVERAGE TORNADO FREQUENCY
Number per year per State

These violent storms occur in all of the States and Canadian provinces and in Alaska. They affect so small a strip that

the chances that any spot will be hit are small. Even in the area where they are most common, the chances that an average farm will be crossed in a century are less than one in a thousand. Many farms are crossed without damage to the buildings; many buildings are demolished without the loss of a human life.

evening. The few destructive nocturnal tornadoes occurred on hot sultry nights. Weather Bureau experts can successfully predict the general occurrence of tornadoes, but not their exact location. As they affect such a tiny fraction of the large area in which they might occur, the benefits derived from official forecasts



Tornadoes are violent whirls started by opposing winds and associated with sharp vertical contrasts in temperature. They start in the clouds and extend to the ground only where the air near the surface is relatively warm, as compared with the higher air. Tornadoes rise above the surface again whenever the surface air is relatively cool. Hence, as to time of day, destructive tornadoes occur chiefly in the afternoon or early

were more than outweighed by the suspension of business, fear and even heart failures, induced. Hence forecasts are no longer issued.

Map 7 is an original one based on State average official data presented otherwise by J. B. Kincer of the Weather Bureau. It shows that tornadoes are more than ten times as frequent near the center of the country as in the Northwest or the West. They are least common in the

most arid region, where, however, violent almost tornado-like dust whirlwinds are frequent.

Tropical Cyclones

The seventh great type of wind is the tropical cyclone. They vary in intensity from mild disturbances which yield much rain, but little wind, to violent hurricanes. They enter the United States chiefly from the West Indies and the Gulf of Mexico, but occasionally one progresses northward along the western coast of Mexico, affecting southern California or Arizona. Storms which developed in the western Pacific as tropical cyclones also enter the United States from the northwest, as Lows. Indeed a considerable share of our Lows are of tropical origin. In addition to Lows of tropical origin entering the United States from the west or northwest, an average of about twenty tropical Lows a year enter the South or pass northward near the Atlantic coast. Of these, three on the average are hurricanes and two have gale winds (32–75 miles per hour). (Visher, *Monthly Weather Rev.*, Vol. 58, 1930, pp. 62–64.)

Map 8 shows the courses followed by various hurricanes which entered the United States. Many of them ceased to be violent storms before they had progressed far over the land, but quite a number caused damage far from the coast, and well out of the tropics. Especially disastrous American hurricanes with the reported loss of life are as follows: 1881, August, coast of S. Carolina and Georgia, 500; 1893, August, coast of Carolina and Georgia, 1,000; 1893, October, New Orleans, etc., 2,000; 1900, September, Galveston, 6,000; 1915, August, Galveston, 280; 1915, September, New Orleans, 275; 1926, September, Florida-Mississippi, 399; 1928, September, Cuba, Florida, 3,000; 1935, September, Florida, 300; 1938, September, Long Island, New England, 682.

Reported property loss was highest in the New England storm, estimated at $400,000,000. The Galveston 1900 storm did an estimated damage of $30,000,000. The Florida hurricanes of 1926 and 1928 caused great tangible property loss, and in addition punctured the Florida boom, causing sharp decrease in property values. Tropical cyclones which lack destructive winds, but which cause very heavy rains, sometimes more than 20 inches in a day, do much unreported damage by causing severe soil erosion. (Visher: Torrential Rains and Soil Erosion, *Jour. of Geology*, Vol. 50, 1942, 96–105.)

THE BLACK LACQUER MYSTERY OF THE GUATEMALA MAYA INDIANS

By Dr. F. WEBSTER McBRYDE

SENIOR GEOGRAPHER, MILITARY INTELLIGENCE SERVICE, WAR DEPARTMENT; ON LEAVE FROM THE DEPARTMENT OF GEOGRAPHY, THE OHIO STATE UNIVERSITY

For years I had seen the shiny black gourds with their delicately incised traceries depicting bright-colored birds and beasts and flowers sold in Indian markets throughout Guatemala. The natives call them *jícaras*, and use them extensively as cups and bowls for their coffee, corn gruel and other drinks. I knew the gourds, some round, some oblong, grew on the calabash or gourd tree (*Crescentia*), common in the drier regions of Central America, and that the dyeing and carving was done in Guatemala by the Indians of the town of Rabinal. But every inquiry I made concerning the source of the beautiful black lacquer brought forth a shrug and a comment to the effect that the process was a secret unknown even by other natives outside of that very village.

Some said the dye was derived from an insect; no one knew what kind. According to a widespread rumor, an American piano manufacturer had offered a reward of $10,000 to any one who could discover the secret process. Though I discounted this story from the first, I became more and more interested in the mystery of the black lacquer. It was not, however, until my fifth Central American expedition that I was able to include Rabinal in my itinerary, early in 1941. And my troubles really began only after I had arrived there.

During my interviews with the Indians regarding their crops, the study of which had brought me to Guatemala on this occasion, I asked a number of men about the lacquer. Invariably they evaded the question, or said they knew nothing about it, that they only farmed, while others worked in lacquer and would tell no one how they did it. Even the officials of the village, who were usually most helpful in anything I needed in my work, said they did not know the magic nor could they find out for me. During the course of the day, I noticed that one of the *regidores* who was assigned to me as an assistant became more and more friendly. He wanted to know all about the United States, and I answered his naïve queries as fully and as graphically as I could. I have always worked with these people on a basis of friendship, never offering money or any kind of bribe for information, and have found this to be the best approach. As the Indians are usually very congenial and have an excellent sense of humor, a few jokes and cigar-

MAP OF THE GUATEMALA AREA
SHOWING THE LOCATION OF THE VILLAGE OF RABINAL, WHERE THE BLACK LACQUER MYSTERY OF THE INDIANS WAS REVEALED.

THE SETTING OF THE VILLAGE OF RABINAL

THE VILLAGE LIES IN AN OPEN VALLEY JUST LEFT OF THE CENTER OF THE PICTURE. THE CLIMATE IS RATHER DRY, AND THE VEGETATION IS MADE UP MOSTLY OF THORN-BUSHES AND CACTI. THE HIGHER MOUNTAINS ARE COVERED WITH PINE AND OAK.

JÍCARO, GOURD OR CALABASH TREE

THE COMMON DRINKING VESSEL, JÍCARA, OF THE GUATEMALA INDIANS LITERALLY GROWS ON TREES. THE WHITE ARROWS POINT TO TWO OF THE GOURDS. THE MOST FAVORABLE HABITAT IS THE LOWLANDS, DRY AT LEAST PART OF THE YEAR. HENCE, THE PACIFIC COASTAL PLAIN, THE EASTERN LOWLANDS AND THE INTERIOR BASINS AND DEEP RIVER VALLEYS, SUCH AS THAT OF RABINAL, ARE THE REGIONS WHERE MOST OF THEM ARE TO BE FOUND. OFTEN THEY ARE INTERSPERSED WITH CACTI AND SPINY BUSHES. NOTE THE PINEAPPLE-LIKE EPIPHYTES GROWING UPON THE BRANCHES.

ettes in most cases will put them in the mood to answer any reasonable questions.

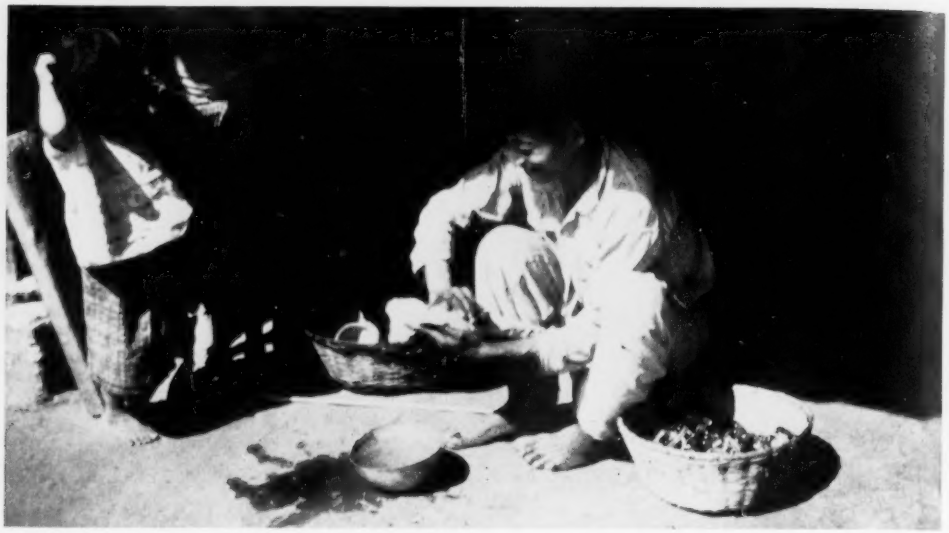
It was encouraging indeed when my newly acquired young Rabinal friend offered to take me to meet the "oldest and wisest" Indian of the village, who was a *brujo*, or medicine man. As usual, when I was introduced to this patriarch, we talked first in generalities, not rushing headlong into the business at hand. I asked about the days and months of the year according to the ancient Maya calendar, which I found to be still in use there as in certain other Indian areas of Guatemala. That day was *ahmác*, next *noj*, then *tijáx* (February 15). Those were ancient Maya day-names, 20 to a month, and 13 months. The old man soon came to feel that I was no stranger among his people. My young companion, pleased and impressed by such favorable developments, explained to the old sage my interest in the black gourds. Several men's names were mentioned, and long-winded discussions ensued, involving many trivialities about the characters in question. Finally the *regidor* got up, saying he would take me to a man who would give me the whole process of the gourd-lacquer. We bade the *brujo* farewell with much ceremony, then walked to the other side of the village, winding through stony alley-ways between half-hidden thatched houses. I had even more than usual the feeling of many unseen eyes following our every move.

At the first house where we stopped, the reticent inhabitants said they no longer did lacquer-work. The next family claimed to have none of the insects just then. At length, after our fifth attempt had provoked only suspicion and evasion, we came upon a man who was amicable and cordial in the extreme. He seemed to be such an old friend of my guide's that not even a statement of our mission disturbed him in the least. He was working on some gourds when we arrived and, at our request, continued so that I could see the various stages in the process. On the dirt floor by his side there was a large basket filled with freshly gathered gourds from the *Crescentia* trees that grow in such numbers throughout the dry interior valleys.

Our host picked up one of these *jícaras*, which are light buff-colored and slightly pimpled. He sprinkled water on it, then with a large, coarse alder leaf, he began to scour it vigorously. Thus smoothed, it was then smeared with a yellowish-

LACQUER SOURCE—A SCALE INSECT
THIS IS AN ADULT FEMALE, ONE-HALF INCH LONG. THE DARK OBLONG OBJECTS BELOW ARE EGGS, LAID IN A COTTONY WEB ON THE TRUNK OF THE JATROPHA, SPONDIAS AND MANGO TREES.

brown wax of the consistency of rather soft butter. I did not interrupt at this step to inquire about the insect from which the wax was derived. That could wait. I wanted to see where the black came from. It proved to be so simple as to be almost disappointing. For the little Indian walked out in his yard to a miniature oven of crudely piled stones, lit a bundle of pitch-pine splints, and started a smudge. Soon there was enough soot in the stone niche to scrape quantities of it into a jar. A little of



SMOOTHING GOURDS FOR LACQUER

A LARGE, ROUGH ALDER LEAF APPLIED LIKE SANDPAPER, WITH PLENTY OF WATER, IS ALL THAT IS NECESSARY TO PRODUCE A SURFACE SMOOTH ENOUGH FOR A POLISH. AFTER A FEW MINUTES OF VIGOROUS RUBBING THE GOURD IS READY FOR THE INSECT WAX. FINISHED PRODUCTS MAY BE SEEN IN THE BASKET IN THE FOREGROUND. THEY ARE PLENTIFUL IN THE LOCAL MARKET, AND OFTEN THEY TRAVEL LONG DISTANCES IN TRADE.

THE BLACK "DYE" THE NATIVES USE IS SOOT

AFTER RUBBING THE LACQUER WAX ON A SMOOTHED GOURD, SOOT IS RUBBED ON AND POLISHED. THE RESULT IS A RICH, JET BLACK WITH A BRILLIANT LUSTER. THE INDIAN IN THIS PICTURE IS USING A SOFT CLOTH AS THOUGH HE WERE POLISHING SHOES. NOTE THE LARGE POT IN WHICH THE SOOT FROM THE OVEN HAS BEEN COLLECTED.

this rubbed on the waxed gourd gave the shiny black finish. The carving was done with a knife held in the right hand as the vessel was turned in the left. Conventionalized leaves and scallops are favorite designs, and sometimes birds and animals. Often they are colored bright red and green. I took still and motion pictures of the entire process.

"How about the insect?" I inquired. "What is it like? Do you have any that I could see?"

Without a word, the gourd-worker disappeared behind a cane partition in a dark corner of his one-room adobe dwelling. He returned a moment later with a handful of white, fluffy material that looked like a cottony mass of spider-webbing. It concealed many minute oval eggs, and a flat, reddish coccid or scale insect (*Llavcia axin*) about a half-inch long. "La madre," he said with a friendly laugh. "We call it *nij*." He was amused at my great interest in all his actions and remarks. Picking up a finished gourd, he put the white "nest," mother insect and eggs inside, then stuffed some corn husks into the mouth of the vessel. "For you," he remarked, handing it to me.

"Three months from now, when the rains start in May," the Rabinalero went on, "I will plant the 'seeds' [eggs]. Bunches of this 'cotton' containing the eggs are tied to the bases of these hedge-plants that we call 'piñon'." He led me into the patio and pointed to a small tree with shiny green branches. I identified it as *Jatropha curcas* L., called "physic-nut" by the British in the West Indies because of the medicinal properties of the seeds. It is said to have fish-poisoning value as well. The "piñon" is the commonest hedge plant in Rabinal because it is the most desirable host for the scale insect.

"During the 'winter' [rainy season]," my informant continued, "these hatch and eat the bark of the piñon. Our harvest is September 15 to 20, when they have grown to full size. We scrape off the *nij*, put them in large jars, and cook them in water. We boil them for three hours, set the soup to cool till the next day, then beat it and stir it for three or four hours inside the house where no one can see. This must be done in the middle of the night. If anyone sees it done, the grease will be no good." This yellowish, buttery fat was what he had smeared on the gourds. It rises to the surface of the water upon cooling and standing, then is agglomerated by stirring. The idea of no one being allowed to see it is

COLLECTING SOOT TO BLACK GOURDS

THICK COATINGS OF SOOT ARE SCRAPED OFF AFTER A SMUDGE IS PREPARED WITH PITCH-PINE IN A SPECIAL "OVEN." THE NEIGHBOR STANDING IN THE BACKGROUND IS WEARING TROUSERS MADE OF AN AMERICAN FLOUR SACK ON WHICH THE LABEL IS PLAINLY VISIBLE ACROSS THE FRONT. SUCH CLOTHING IS NOT UNCOMMON IN GUATEMALA, NOW THAT HAND WEAVING IS DECLINING.

CARVING THE BLACKENED GOURD

THE DECORATION OF THE JÍCARAS IS DONE WITH A SHARP METAL CARVING TOOL HELD STATIONARY IN THE RIGHT HAND AS THE GOURD IS ROTATED WITH THE LEFT. THE INCISED DESIGNS SHOW WHITE WHERE THE GOURD IS EXPOSED. OFTEN THEY ARE FURTHER ELABORATED BY BRIGHT COLORS, APPLIED WITH A BRUSH.

a device for keeping the secret of the process.

Strictly speaking, then, it is lac wax, commonly used in shellac, and not a true lacquer, which is derived from the sap of certain trees.

Soot is not the only pigment used in the gourd-lacquer craft. *Achiote* (*Bixa orellana* L., usually called *anotto* in English) is a common source of dull red. The finish in both instances is remarkably durable, and repeated washing even in warm water will not remove the color or luster. Only through boiling several times can the lacquer be removed by water.

As Rabinal is the only jícara-fashioning village in all Guatemala, so in El Salvador the craft is practiced only at Izalco. This is one of the few predominantly Indian communities still to be found in the latter republic. In Mexico the chief gourd-lacquer center is Tlacotalpan, in the state of Vera Cruz. There are several trees besides *piñon* employed as host-plants for the scale, such for example as *Spondias lutea,* usually called "jobo," which has a poor plum-like fruit.

The species name "axín," sometimes "axí" or "ají," is often applied to the fatty substances as well as to the insect. It probably is derived from the old Spanish word "ají" (pronounced a-hée) which was the common colonial term for chile (*Capsicum* spp.). There is a strong resemblance between the reddish, oval-shaped, wrinkled insect and small varieties of dried chiles.

It is not unlikely that the ancient Maya Indians coated their beautifully carved and painted limestone buildings, and the decorated lintels of zapote wood, with this waxy substance. Such a suggestion has been mentioned in Urbina's "Naturaleza," quoted by Paul C. Standley in his "Trees and Shrubs of Mexico," which includes several interesting paragraphs about the insect and its host plants. In Yucatan, where the Maya reached their final peak of spectacular architectural attainment, the *axín* is commonly cultivated for its wax. There is little doubt about the antiquity of the use of the lacquer. The tree-gourds were also widely used by the Indians before the Conquest. Captain Oviedo, the first Spanish writer on natural history in the New World, early in the sixteenth century, described fine cups of "higueras" (jícaras) in Darien that had handles of gold, "fit to offer to any mighty king to drink out of without reproach." These had come in trade, mainly from Nicaragua. And still today, colorful tree-gourds travel on the backs of merchants to crowded markets throughout the Indian country of Central America.

BOTANIZING IN THE HIGHER ALLEGHANIES

By Dr. EARL L. CORE

PROFESSOR OF BOTANY, WEST VIRGINIA UNIVERSITY

FROM the standpoint of majestic mountain scenery and rare or otherwise interesting plant life, there is scarcely a more fascinating area in the entire mid-Appalachian region than is included in the Pendleton County offset in West Virginia's eastern boundary. Pendleton is noteworthy in having the most rugged relief of any county in West Virginia; it includes the highest elevation in the State, 4,860 feet, on Spruce Knob, and the lowest elevation in the county, 1,155 feet, making a total difference in altitude of 3,705 feet. Geologically, its rocks range in age from Ordovician to Carboniferous, even including two small igneous dikes, providing in a relatively small area (696 sq.mi.) a most remarkable series of plant habitats. The recent completion of a splendid highway system has made this charming mountain country readily accessible to the motoring botanist.

The high crest of Alleghany Mountain forms the western boundary of the county, and the east-bound motorist on U. S. Route 33 who stops his automobile at the county line finds spread out before him in a tangled mountain mass the alluring prospect of a most delightful excursion.

To the left the broad grassy slope of Alleghany rises up and up to cloud-capped Green Knob (4,660 feet), beyond which stretches far to the northwards the windswept, uninhabited expanse of Roaring Plains, a vast monotonous heathland broken only now and then by bold monadnocks of Pottsville Conglomerate or the skeleton of an ancient fire-stricken tree. Footpaths of mountain folk criss-cross the Plains, which every

Paul H. Price, West Virginia Geological Survey

FIG. 1. THE TOWERING MASS OF SENECA ROCKS

LIFTS ITS RAGGED CREST NEARLY 1,000 FEET ABOVE NORTH FORK RIVER AT THE BASE.

William E. Ramsey

FIG. 2. SPRUCE KNOB, THE HIGHEST ELEVATION IN WEST VIRGINIA

summer yield thousands of gallons of blueberries, a crop which investigators at West Virginia University are now attempting to improve by selection and hybridization. Here and there poorly drained depressions provide suitable conditions for alder-invested sphagnum bogs, with trailing cranberries (*Vaccinium macrocarpon*) and insectivorous sundews (*Drosera rotundifolia*), studded with mountain holly (*Nemopanthus mucronata*). Occasional gnarled and twisted Table Mountain pines (*Pinus pungens*), pitch pines (*P. rigida*) or red spruces (*Picea rubens*) represent Nature's faltering efforts to reclothe the immense waste, whose forests were destroyed years ago by oft-repeated burnings.

Dropping down the eastern flank of Alleghany the motorist twists and turns around horseshoe curves or skirts the

Jesse F. Clovis

FIG. 3. U. S. ROUTE 33 REACHES THE SUMMIT OF NORTH FORK MOUNTAIN IN ONE OF THE FEW PASSES THAT CUT THROUGH THE MOSTLY UNIFORM CREST.

dizzy margin of deep ravines, with sheer drops of hundreds of feet, finally descending to the headwaters of a tributary of Seneca Creek, which flows between high mountain walls past occasional isolated cabins to Mouth of Seneca, where the towering mass of Seneca Rocks lifts its ragged crest nearly 1,000 feet above North Fork River at the base (Fig. 1). The Rocks are composed of White Medina Sandstone (quartzite), which formation, like a great plank set on edge and backed up on each side with a buttress of earth, forms the backbone of a ridge extending the entire length of the county and beyond, like the Great Wall of China. The disintegrated fragments of quartzite provide congenial habitats for very few plants, one of the most characteristic being the silvery whitlow-wort (*Paronychia argyrocoma*), which in West Virginia is never found off the White Medina.

Driving south along the North Fork River between lofty deep-green Spruce Mountain on the right and towering crag-topped North Fork Mountain on the left, one is afforded innumerable opportunities to examine an interesting ruderal flora. Carrying detritus from a bountiful storehouse of infinitely varied limestones, sandstones, shales and other rocks, the river flows over and between beds of gravel and rounded boulders whose instability causes frequent shifts in the course of the stream and prevents the permanent establishment of plant life. Scores of species of introduced plants, some of them unknown or rare elsewhere in the State, here find suitable conditions for growth, the pioneer habitats providing freedom from competition. Among more common weeds there may be observed the rue (*Ruta graveolens*), toadflax (*Linaria Elatine*), marijuana (*Cannabis sativa*), mole plant (*Euphorbia Lathyrus*), blue thistle (*Echium vulgare*), herba impia (*Gifola germanica*) and cudweed (*Gnaphalium uliginosum*).

Forests against the precipitous river bluffs include, among commoner trees, the arbor-vitae (*Thuja occidentalis*), with the toothache-tree (*Xanthoxylum americanum*) and aromatic sumac (*Rhus aromatica*) as more or less common shrubs, and the curiously distributed Canby's mountain-lover (*Pachistima Canbyi*) now and then forming a ground cover.

Just beyond Riverton the traveller may turn right from the paved federal highway to make the nine-mile climb over a narrow but smooth forest road to the summit of Spruce Knob, the highest

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FIG. 4. GERMANY VALLEY

HEMMED IN BY THE HIGHEST MOUNTAINS OF THE MID-APPALACHIAN REGION.

elevation in West Virginia (4,800 feet, Fig. 2). Conditions have been greatly improved since 1925 when Rydberg, travelling by automobile to the top of the mountain over a steep rough trail, knocked the bottom out of the crankcase on a protruding rock and had to have his motor hauled in by a team of horses. In a ravine near the Knob Rydberg found a monkshood which he named *Aconitum vaccarum*, because it was said to cause cattle poisoning on the great government pasture range; it does not seem, however, to differ specifically from *A. reclinatum*, found in western Virginia almost a century earlier by Asa Gray. Near the crest of the mountain is the remnant of a red

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FIG. 5. NORTH FORK MOUNTAIN
TOPPED WITH MASSIVE WHITE MEDINA SANDSTONE IN GREAT LICHEN-BLACKENED CLIFFS.

spruce-yellow birch forest, with the white wood sorrel (*Oxalis montana*), here, as everywhere, the most abundant and characteristic plant beneath the spruce trees, while the creeping snowberry (*Chiogenes hispidula*) may be seen. In moist open spots American hellebore (*Veratrum viride*) is common. The rocky exposed knob yields few species of plants. Red spruces occur in patches, their asymmetrical crowns demonstrating vividly the effect of the prevailing winds. Common shrubs are Alleghany Menziesia (*Menziesia pilosa*), mountain ash (*Sorbus americana*), mountain holly (*Ilex monticola*), Canada honeysuckle (*Lonicera canadensis*), wild red raspberry (*Rubus strigosus*), mountain cranberry (*Vaccinium erythrocarpon*), and various species of blueberries. Other plants with a distinct northern range include dwarf cornel (*Cornus canadensis*), bristly sarsaparilla (*Aralia hispida*), skunk currant (*Ribes prostratum*), fringed black bindweed (*Polygonum cilinode*), brownish sedge (*Carex brunnescens*), and the pearly everlasting (*Anaphalis margaritacea*). The animal life is no less interesting. Deer are occasionally found. Wolves, formerly very destructive to cattle and sheep, have been extinct since about 1890, but there still occur a few black bears, wild cats and varying hares. Birds are represented by such species as the veery, winter wren, the Canadian warbler and the golden-crowned kinglet. Rattlesnakes are common.

Returning to the valley of the North Fork River, the traveller passes the great barrier of White Medina through spectacular Judy Gap and begins the long, tortuous ascent of North Fork Mountain, twisting over foothills and gaining their summits only to find still higher elevations lying ahead. At one point many motorists come to a halt (Fig. 4), overcome by the magnificent beauty of the great oval of Germany Valley, hemmed in by the highest mountains of the mid-

Appalachian region, with other ranges far away in the background, gradually fading away into the blue. At last the winding road reaches the summit of North Fork in one of the few passes that cut through the mostly uniform crest (Fig. 3), topped with massive White Medina in great lichen-blackened cliffs (Fig. 5). During the severely cold weather of February, 1899, it is told, a huge rock mass fell out of a precipice and plowed a broad path westward down the mountain-side. The avalanche, occurring just before dawn, awakened the scattered mountain people, who thought it had been an earthquake. On the inhospitable rocky ledges *Paronychia argyrocoma* is again found, while the three-toothed cinquefoil (*Potentilla tridentata*) here is common, forming one of the two county records in West Virginia. A good stand of many acres of red pine (*Pinus resinosa*) represents the southernmost known station of this valuable forest tree and provides seeds for the State's vast reforestation program (Fig. 6). In this wild rock-strewn mountain top the naturalist is startled, too, in beholding the snow-white trunks of paper birch (*Betula papyrifera*), the only colony in West Virginia (Fig. 7). Also found here are the purple clematis (*Clematis verticillaris*), mountain maple (*Acer spicatum*), mountain holly (*Ilex monticola*), the large columbine (*Aquilegia coccinea*) and "five-leaved" gentian (*Gentiana quinquefolia*). Rydberg's *Heuchera alba*, the type locality of which is on Snowy Mountain, a few miles to the south, is quite common against North Fork. Lily-of-the-valley (*Convallaria majalis*), amazingly, occurs as a native plant in mountain fastnesses on North Fork.

Dropping down the east side of North Fork, the automobilist comes to tidy

U. S. Forest Service

FIG. 6. RED PINE ON NORTH FORK MOUNTAIN

THIS AREA IS THE SOUTHERNMOST KNOWN STATION FOR RED PINE.

Franklin, Pendleton's county seat, and the valley of the South Branch River. Here are broad river bottomlands, with fields of waving corn or hundreds of grazing cattle; Thorn Creek, with its deep ravines and great natural amphitheatre, the Reunion Ground, with the snowy trillium (*Trillium nivale*) in abundance, one of the few localities in the State; and incredible Smoke Hole, where, amidst a land of towering cliffs, sunless canyons and rushing mountain torrents, a few isolated log houses cling precariously to steep mountain sides, the crested coral-root (*Hexalectris spicata*) finds the northernmost extension of its range and the tall larkspur (*Delphinium exaltatum*) its only West Virginia station. In a rocky roadside along the valley highway the rusty woodsia (*Woodsia ilvensis*) is found in the only known locality in the State. Bur oak (*Quercus macrocarpa*) and swamp white oak (*Q. bicolor*), rare elsewhere in West Virginia, are frequent here, and chinquapin (*Castanea pumila*) finds its northernmost State locality. Painted cup (*Castilleja coccinea*) carpets moist meadows with scarlet.

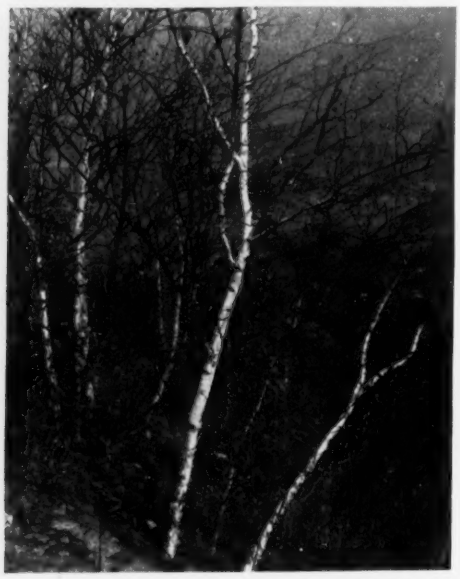

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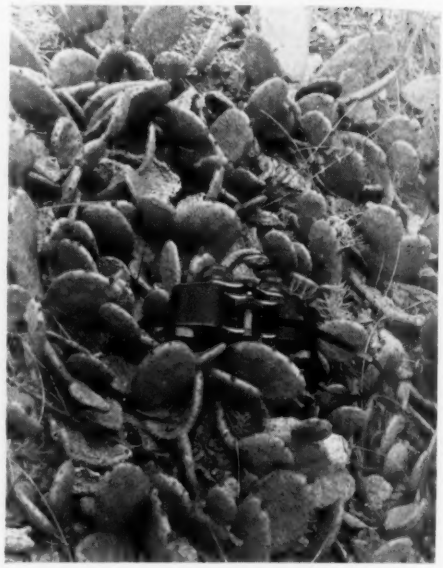
FIG. 7. ON NORTH FORK MOUNTAIN

ON THIS ROCK-STREWN CREST THE NATURALIST IS STARTLED AT BEHOLDING THE SNOWY-WHITE TRUNKS OF PAPER BIRCH, THE ONLY COLONY IN WEST VIRGINIA.



Jesse F. Clovis

FIG. 8. PRICKLY-PEAR CACTUS

COVERS SHALE BARRENS WITH SUCCULENT SLABS.

Through rhododendron-clothed Hiveley Gap, the highway reaches the South Fork, or Moorefield, River. Here outcrops of Devonian shales weather to produce the famous shale barrens, inhabited by a bizarre group of rare plants whose nearest relatives often are found in the Ozarks or the semi-arid regions of the Southwest. The late sickle-pod (*Arabis serotina*) on the shales near Brandywine flowers two months later than the related *A. laevigata;* the remarkable Kate's Mountain clover (*Trifolium virginicum*) rewards the search of the persistent seeker; prickly pear cactus (*Opuntia compressa*) (Fig. 8) covers the bare ground with great succulent slabs; the showy evening primrose (*Oenothera argillicola*) provides color for the drab landscape; mountain pimpernel (*Pseudotaenidia montana*) the discriminating botanist separates from the commoner

Taenidia integerrima; the common and widespread *Paronychia fastigiata* shades into *P. montana* on the barrens; the velvet "bindweed" (*Convolvulus*) grows erect to unfold its ephemeral white flowers; the hoary plants and yellow flowers of the everlasting groundsel (*Senecio antennariifolius*) add an interesting bit of attraction; Harris' goldenrod (*Solidago Harrisii*) leads the parade of all the goldenrods, sometimes blooming for Memorial Day; while late in the year the shale barren aster (*Aster oblongifolius*) tinges the barrens with pink.

At last the botanist begins the long ascent of Shenandoah Mountain, the final stage of his excursion through this happy-hunting-ground. Higher and higher, 'round ever-dizzier curves, the twisting highway mounts, as if determined in the last few moments to excel anything yet exhibited, and from the summit, at the foot of old High Top (elevation 4,107 feet), a never-to-be-forgotten scene invites the traveller to return. The rare mountain andromeda (*Andromeda floribunda*) is common along roadsides at the crest and *Habenaria bracteata* occurs here in the only reported colony in West Virginia.

Resuming his journey, the motorist sets his face eastward into Virginia. In his jaunt of less than 100 miles across high and low points through Pendleton County the range of climate had been the equivalent of a trip from the Carolinas to Canada, with a touch of the Southwest thrown in for good measure.

CARRIÓN'S DISEASE

A PUBLIC HEALTH PROBLEM IN PERU

By Dr. CALDERON HOWE

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Of all the weird and exotic diseases that occur in tropical and subtropical climates, there are few that can equal "la enfermedad de Carrión" in offering challenging problems to scientists and medical men. Carrión's disease includes two clinical entities which are now known to be caused by the same germ, and which have fired the imagination of investigators from many parts of the world.

The first of these, *verruga peruana*, has been known for many decades to be endemic in certain districts of Peru, and is said by some historians even to have occurred among the conquering troops of Pizarro. It is common in children, and among the natives is often included in the roster of the usual childhood diseases, such as measles, chicken pox, and the rest. In a large number of cases, very often among nonimmune adults newly arrived in these endemic areas, the eruption is preceded by the severe and often fatal anemic fever, *Oroya fever*, the other clinical entity of Carrión's disease.

Oroya fever came into prominence for the first time in 1870 during the construction of the central railway from Lima, on the coast, to Oroya, a town situated in the interior beyond the highest point in the Peruvian Andean chain. Seven thousand men—according to the legend, one man for every tie in the railroad—are said to have perished in a relatively short time, most of them in an epidemic of debilitating fever, thereafter known as *Oroya fever*. The fact that many indi-

BARREN ASPECTS OF PERUVIAN MOUNTAINS
RELIEVED ONLY BY THE NARROW STRIP OF GREEN VALLEY FLOOR.

"PUENTE VERRUGAS," OR AS IT IS NOW CALLED, "PUENTE CARRIÓN"
ON THE CENTRAL RAILWAY, SPANS ONE OF THE LARGER "QUEBRADAS," WHICH IS A NOTORIOUS SITE FOR CONTRACTING CARRIÓN'S DISEASE ALTHOUGH NO HUMAN HABITATION EXISTS FOR MILES.

viduals recovered and developed the typical eruption of "verruga" led to the suspicion that this eruption and *Oroya fever* might be related.

On August 27, 1885, a Peruvian medical student, Daniel A. Carrión, inoculated some blood and tissue from a human *verruga* nodule into the skin of both his forearms. On October 5th of the same year, he died of typical *Oroya fever*. This crucial experiment indicated for the first time that the eruptive disease and *Oroya fever* were indeed parts of the same disease, which now has come to be named after this Peruvian national hero. The deductions made from his sacrifice have been abundantly confirmed in later years by extensive scientific investigation, both by Peruvian and foreign workers.

Carrión's disease is almost unique in having had, until recently, a strictly nationalistic geographical distribution. It is seen chiefly along the Pacific slope of the Peruvian Andes, between eight hundred and three thousand meters. In 1939, however, it was reported for the first time from Colombia, and in 1940 from Ecuador.

In Peru, the regions where this affliction is endemic are fairly well outlined, and are confined almost solely to the foothills. This part of the country often defies description in its ever-changing pattern of deep purples, light ochres, and passing shadows made by the mountain shapes and cloud formations. As one climbs from the seacoast, after traversing the narrow coastal plain (perhaps at the mercy of an experienced but over-enthusiastic Peruvian "chofer"), one passes through steep gorges and valleys, the "quebradas" as they are called, between cold and barren hills. The width of the road has narrowed down to slightly more than that of the car, and one holds one's breath as the next hairpin turn is rounded, because of the fairly good possibility of meeting an equally enthusiastic "chofer" coming the other way with far less control over the brakes of his "camioneta." There will then be hair-raising backing and filling with glimpses over the shoulder into the bottomless ravine below as the two vehicles squeeze by each other in a widened place in the road made expressly for such maneuvers.

SANTA EULALIA RIVER VALLEY
AT THE UPPER LIMIT OF THE ENDEMIC REGIONS. SCENES SUCH AS THIS RECALL TO MIND THE THEATRICAL EFFECTS OF THE GRAND CANYON.

The flora in these regions consists mainly of cacti and low-growing hardy shrubs, notably varieties of the Euphorbia family. During the rainy season in the mountains, from January to April, the peaks are often capped by clouds which may part momentarily to reveal a transient green tinge high up on

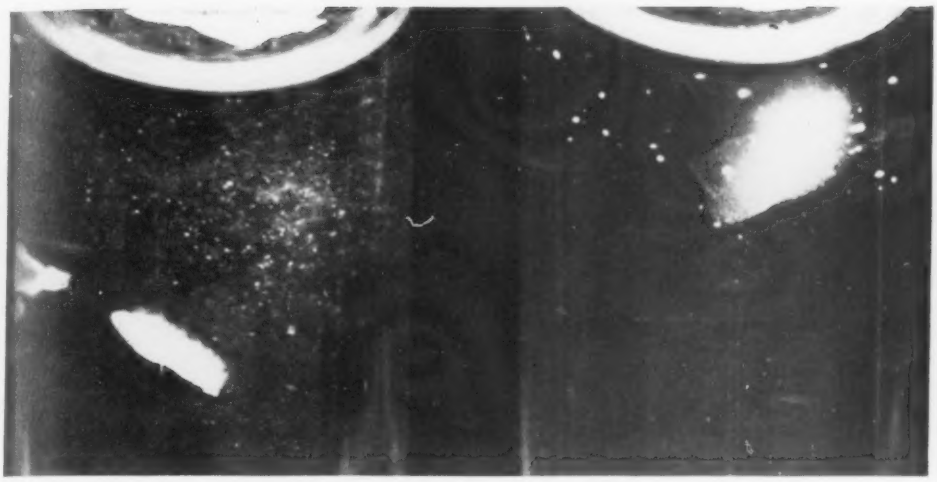
the hillsides. This warm dash of color will disappear as the rains diminish, leaving the peaks a cold brown-gray hue for the larger part of the year. Only the narrow floors of the valleys are cultivated, yielding sparse crops of cotton, coffee, and bananas, the fields being irrigated through the remains of early Inca ditch systems. High up on the mountain slopes, miles away, are visible further

SPARSE CROPS
OF COTTON, BANANA AND COFFEE ARE COAXED OUT OF ARTIFICIALLY IRRIGATED AND CAREFULLY COUNTED ACRES OF SOIL.

reminders of the once-great Inca civilization in the form of countless terraces moulded from the sloping terrain, and calculated to squeeze the last corner of tillable soil from the land. It is among the inhabitants of these valleys that the "enfermendad de Carrión" occurs so widely.

Oroya fever itself deserves special mention, as there are few infections that can equal its dramatic swiftness of progression in severe cases. It is, fundamentally, a blood-destroying fever, which prostrates its victims by rapidly reducing the normal complement of red blood corpuscles often by more than two thirds. Examined under the high-powered microscope, many red blood cells are seen to contain small rod-like and punctate bodies, first described by Dr. Barton, in 1905, in Lima. These organisms, named *Bartonella bacilliformis*, were later proved to be the germ of Carrión's diseases, that is both *verruga peruana* and *Oroya fever*. The native afflicted with fulminating *Oroya fever* presents an impressive picture—of death-like pallor, marked in spite of deep natural pigmentation, occasionally jaundice, extreme weakness, and often the drowsiness ominous of impending defeat of the natural forces of immunity by the invading microorganism. If the patient recovers, he will almost certainly develop the typical eruption of *verruga peruana*, the first signs of which are always eagerly awaited and are welcomed with relief. From rough estimates, it is said that about forty per cent. of the cases of frank and severe *Oroya fever* terminate fatally.

The picture of *verruga peruana*, which may or may not be preceded by *Oroya fever*, is also striking but is far less serious. The face and extremities may be covered with bright cherry-red warts, which bleed profusely when tampered with, but which finally disappear without leaving the slightest trace or scar. The eruption may also occur in the shape of a few large painful subcutaneous nodules, or, in other cases, as very small red nodules on the skin, almost uniform in size, scattered in profusion over the whole body. The actual eruption, whatever form it may assume, may last many months and is entirely benign, except



THE GERM OF CARRIÓN'S DISEASE CAN BE CULTURED ARTIFICIALLY

IT GROWS IN FINE WHITE PEARLY COLONIES OF MANY THOUSANDS OF ORGANISMS. SUCH COLONIES, OFTEN BARELY VISIBLE TO THE NAKED EYE, ARE HERE SEEN SUSPENDED IN NUTRIENT MEDIUM.

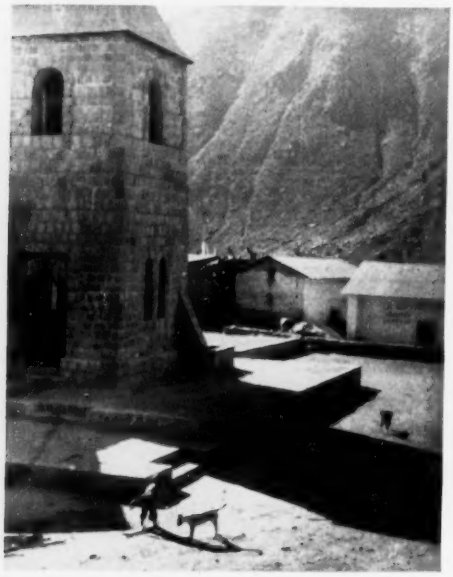
for the discomfort it may cause the patient. When uncomplicated by any extensive secondary infection, it is never fatal. It is, furthermore, not directly contagious, although the germ can be recovered in culture from the nodules.

INCA TERRACES TOWARD THE PEAKS OF THE MOUNTAINS

CALCULATED TO CATCH WATER FROM THE CLOUDS WHILE THESE PERSIST IN THE RAINY SEASON.

UNSIGHTLY VARIEGATED WARTS
SCATTERED OVER THE EXTREMITIES, AND IDEAL SITES FOR SECONDARY INFECTION. THIS IS THE COMMONEST FORM OF *verruga peruana*.

To transmit the disease from one person to another, requires the intermediary services of the wild sandfly, chiefly the species *Phlebotomus verrucarum*. The fact that the infection can be contracted in the endemic regions only during the hours of darkness and that one can traverse these same regions with perfect safety during the day is explained by the habits of this blood-sucking insect. It is smaller than a mosquito, inhabits the crevices and caves of the barren mountainside, and attacks man and animals only during the night. It is only the female of the species that bites. During the day, sandflies can be picked with ease from the cracks of a stone wall, or be caught in a lethargic state in a dark corner of a native hut. That this insect does carry *verruga* is proved by the fact that the specific germ has on numerous occasions been isolated in pure culture from specimens of *Phlebotomus* caught in the endemic regions. The source of their infection still remains a mystery, and both animals and plants of various kinds have been indicted on many pretexts, none of them proved. From recent surveys, however, it has become evident that an appreciable portion of the native population, namely from four to seven per cent., carry the germ in their blood stream without suffering any of the symptoms of Carrión's disease. These individuals may have had the disease in the past. It is possible that they might be called "carriers," along with active cases of the disease, are the chief source from which sandflies may during the night obtain an infected "blood meal," and so spread the disease to nonimmune persons. It is thus obvious that complete protection can be guaranteed the newcomer in these areas where *Phlebotomus* occurs only in escaping its range either by ascending into the sierra to a point higher than three thousand meters, or by descending almost to sea-level. Even one night's sojourn without protection from fine-meshed bed nets is inviting disaster in the form of almost certain attack at the hands of the ubiquitous *Phlebotomus*. The writer recalls seeing one unfortunate individual, the victim of such an attack during one of the latter's first nights in the endemic zone. He displayed his two forearms literally covered with small reddened dots, the mark



IN CALLAHUANCA, A SMALL VILLAGE
OF SEVERAL HUNDRED INHABITANTS, IN THE LOWER PART OF THE SANTA EULALIA VALLEY. TYPHOID FEVER, AND DERMAL LEISHMANIASIS, OR "ORIENTAL SORE," OCCUR HERE IN ABUNDANCE.

of the "titira," as the sandflies are locally known. Such a sight encourages even a Peruvian who has not had *verruga* to hasten back to the coast by sunset.

Many different forms of treatment for Carrión's disease have been tried, some good, others harmful, some traditional, others nearer the scientific. None of them has been consistently successful. There is, as yet, no specific therapy for this infection, as there is, for instance, for syphilis or lobar pneumonia. There is, furthermore, no effective means of immune prophylaxis, such as one can obtain for smallpox or typhoid. It is thus obvious that the disease renders virtually uninhabitable large portions of the country for individuals who have not had either form of Carrión's disease, or who come from regions where it is not endemic. To add to the difficulty, there is no effective method for controlling or exterminating the sandfly, the geographical distribution of which determines the extent of the areas where Carrión's disease is endemic. Its breeding habits offer no opportunity, as do those of the malaria-carrying mosquito, for stopping the cycle of its development, and so diminishing the spread and incidence of the infection it carries.

It is for all of these reasons that Carrión's disease seems at the moment firmly entrenched in its original habitat, and indeed has already shown definite signs of spreading. The recent serious epidemic in Colombia is good indication of this trend. Consequently, it offers a definite and potentially serious public health problem in this age of shifting populations and extensive military movement, and taxes the ingenuity and skill of bacteriologist, entomologist, and "medico" alike.

Photomicrograph, Dr. Marshall Hertig

THE VECTOR OF CARRIÓN'S DISEASE AND EPIDEMIOLOGICAL KING-PIN, *Phlebotomus verrucarum*. WHEREVER THE "TITIRA" IS FOUND, CARRIÓN'S DISEASE WILL OCCUR.

SO-CALLED "MILIARY" TYPE OF *verruga* ERUPTION WHERE THE NODULES ARE MORE OR LESS OF THE SAME SIZE AND DO NOT BLEED SO PROFUSELY.

CULTURAL INFLUENCES OF PENNSYLVANIA'S MOUNTAIN GAPS

II. IMPROVING THE ROUTES

By Dr. BRADFORD WILLARD
PROFESSOR OF GEOLOGY, LEHIGH UNIVERSITY

The Canals Take over

Beginning as a local means of making detours around rapids or other obstructions along the rivers, the concept of the continuous canal took hold. The obvious routes were along the river valleys through the gaps. Even with the best of locks, hill climbing is not one of the canal boat's greatest accomplishments! The valleys offered the low gradients. Here, too, could be obtained an adequate supply of water essential to the successful operation of the canals. Likewise, construction costs would be reduced in places where deep stretches of river could be joined by canals. Established commercial routes already existed along the rivers, and towns were growing with the attendant concentrations of population.

Since the present discussion is chiefly of Pennsylvania, the Erie Canal may be passed by, though its importance is fully recognized because it alone connected the Atlantic seaboard directly with the Great Lakes. Canals grew westward in the states to our south. The Chesapeake and Ohio Canal followed the Potomac River; others were projected along the James and Tennessee River Valleys. Because of close relations to Pennsylvania, the Chesapeake and Ohio deserves a little more recognition here. As originally planned this canal was to link the seaboard and the Ohio River via the Potomac. Yet, although its value was recognized by George Washington, it was not until 1828 that the undertaking was treated as a whole. Prior to that year it amounted only to short detours around rapids. In the same year that the canal was started the Baltimore and Ohio Railroad commenced to advance its tracks west from Baltimore. Canal and railroad met at Point of Rocks, Maryland. The railroad arrived first, but there was a dispute over the right of way, settled only when the railroad crossed to the Virginia side and drove a tunnel. The canal proved of some importance during the Civil War in the transportation of troops and supplies, and, like the Baltimore and Ohio Railroad, it was an object coveted by both armies.

The canals of Pennsylvania were numerous. Many were associated, either at their beginning or subsequently, with the development of hard coal fields. We refer, of course, to the canals in the east; that is, those crossing the mountains by way of the gap gateways to anthracite.

Because the Erie Canal and those projected along the Potomac and James Rivers were taken as a serious threat to the commerce of Philadelphia, and because the Baltimore and Ohio Railroad was adding to the menace and threatening travel over the National Road, agitation was keen in Pennsylvania for a canal system of its own. Nowhere in Pennsylvania could a canal be economically or feasibly constructed completely across the mountains and plateaus to join the waters of the upper tributaries of the Ohio with those of streams flowing into the Atlantic Ocean. The high, eastward-facing escarpment of the Allegheny Plateau, the Allegheny Front of physio-

graphic literature, terminated western canal-building in the 1820's. An exception might have been made along the upper waters of the West Branch of the Susquehanna River, and the Sinnemahoning River. Not only, however, was this a difficult route, but there was no commerce to call for a canal there. The country was an unknown wilderness as late as 1836. It was in the summer of that year that Henry D. Rogers, first state geologist of Pennsylvania, made a reconnaissance survey from Philadelphia to Lake Erie. Rogers, telling of conditions in the northwestern counties, reports that the country was too wild for penetration even with the pack train. Field equipment and camping outfit had to be back-packed by men hired for that purpose.

Albeit a canal across the Allegheny Front was out of the question, the problem of getting boats up and over was solved. The Pennsylvania Canal came up the Susquehanna and followed as far as Hollidaysburg the Juniata River from its confluence with the Susquehanna north of Harrisburg. For a hundred miles it passed through one water gap after another. At Hollidaysburg the famed Portage Railroad was constructed to transport passengers and to draw the boats themselves up the escarpment. Today, travelers over U. S. Route 22 may mark where the old line climbed the scarp, sketched as it is by remnants of grades ("planes") and the masonry of the ancient roadbed. Once at the top, a similar trip down the west slope brought freight and passengers finally to Johnstown, where the boats resumed the more congenial environment of the canal down the Conemaugh River. A vivid description of this passage of the Alleghenies comes from the "American Notes" of Charles Dickens:

> We left Harrisburg on Friday. On Sunday morning we arrived at the foot of the mountain, which is crossed by railroad. There are ten inclined planes; five *a*scending, and five *de*scending; the carriages are dragged up the former, and let down the latter, by means of stationary engines; the comparatively level spaces between, being traversed, sometimes by horse, and sometimes by engine power, as the case demands. Occasionally the rails are laid upon the extreme verge of a giddy precipice; and looking from the carriage window, the traveller gazes sheer down, without a stone or scrap of fence between, into the mountain depths below. The journey is very carefully made, however; only two carriages travelling together; and while proper precautions are taken, is not to be dreaded for its danger.
>
> It was very pretty travelling thus, at a rapid pace along the heights of the mountain in a keen wind, to look down into a valley full of light and softness; catching glimpses, through the tree-tops, of scattered cabins; children running to the doors; dogs bursting out to bark, whom we could see without hearing; terrified pigs scampering homewards; families sitting out in their rude gardens; cows gazing upward with a stupid indifference; men in their shirtsleeves looking on at their unfinished houses, planning out tomorrow's work; and we riding onward, high above them, like a whirlwind. It was amusing, too, when we had dined, and rattled down a steep pass, having no other moving power than the weight of the carriages themselves, to see the engine released, long after us, come buzzing down alone, like a great insect, its back of green and gold so shining in the sun, that if it had spread a pair of wings and soared away, no one would have had occasion as I fancied, for the least surprise. But it stopped short of us in a very business-like manner when we reached the canal: and, before we left the wharf, went panting up this hill again, with the passengers who had waited our arrival for the means of traversing the road by which we had come.

Work on the canal system in Pennsylvania was well under way by the year 1834, which saw the completion of the Main Line. This principal canal followed the Susquehanna and Juniata Rivers to Hollidaysburg (Fig. 7). Another went up the North Branch of the Susquehanna to Athens; yet another along the West Branch to Farrandsville. The Schuylkill Canal reached to Port Clinton, the Lehigh to Mauch Chunk and White Haven. Far to the east the Delaware and Hudson Canal was built to Honesdale. Up Swatara Creek a branch

FIG. 10. DELAWARE WATER GAP

THIS VIEW IS SOUTHEAST FROM THE PENNSYLVANIA SIDE. SCENICALLY THE MOST FAMOUS OF ALL THE PENNSYLVANIA GAPS, IT HAS PROVED OF LESS IMPORTANCE COMMERCIALLY BECAUSE IT DOES NOT GIVE DIRECT ACCESS TO THE ANTHRACITE COAL FIELDS.

from the old Union Canal penetrated the mountains to Pine Grove. All these canals followed the stream valleys. In so doing they usually attained satisfactory gradients but were in constant danger from damage or ruination by floods.

Curiously enough, no canal was built through the Delaware Water Gap, although this notch was early traversed by a wagon road, later by railroads. The reason appears to be twofold, first that the Delaware River above the Gap makes a sharp turn northeastward away from the anthracite fields (Fig. 7), and second that the country north of the Gap consists of ridges and plateau heights not given to agriculture. Therefore, the two commonest reasons for canal-building in the east, coal and produce, were lacking as incentives for a canal through Delaware Water Gap. The lower reaches of the river were paralleled by a canal, but this is foreign to the scope of this paper, since it passed through no gaps.

On the other hand, the upper waters of the Delaware River saw the construction in the 1820's of the Delaware and Hudson Canal to bring coal out of the northern anthracite basin. Before it was built coal lands had been surveyed by the Wurtz brothers about 1812. Their findings induced men to devise means of getting the novel fuel to market. Options were taken in the Lackawanna Valley, and an outlet was provided through the Delaware and Hudson Canal along Lackawaxen and Wallenpaupack Creeks to the deep-cut valley of the Delaware, a distance of 16.5 miles. Here, as on the main line of the Pennsylvania Canal over the Allegheny Front, there grew up a combination of railroad and canal. From Carbondale to Honesdale an ancestral roller-coaster, the old "Gravity Road," took over where the grade was too steep for canal construction. The cars carried the product of the mines down to Honesdale, there to be transferred to canal boats. Abandoned today, only the remnants of the canal remain—a bit of towpath, a lock's crumbling masonry. The tree-grown railroad grades mark the line of the gravity road of a hundred years ago. It is indeed worth remembering that in connection with this very project the British-built locomotive, the *Stourbridge Lion*, was tried but was given up when the weak, wooden track was judged inadequate to support its weight. Today the ancient machine is commemorated by a monument at Honesdale.

The Delaware and Hudson Canal was only one of several built into the anthracite fields. Although, as remarked, some were not intended primarily for coal haulage, all eventually came to look upon such freight as their chief asset. The

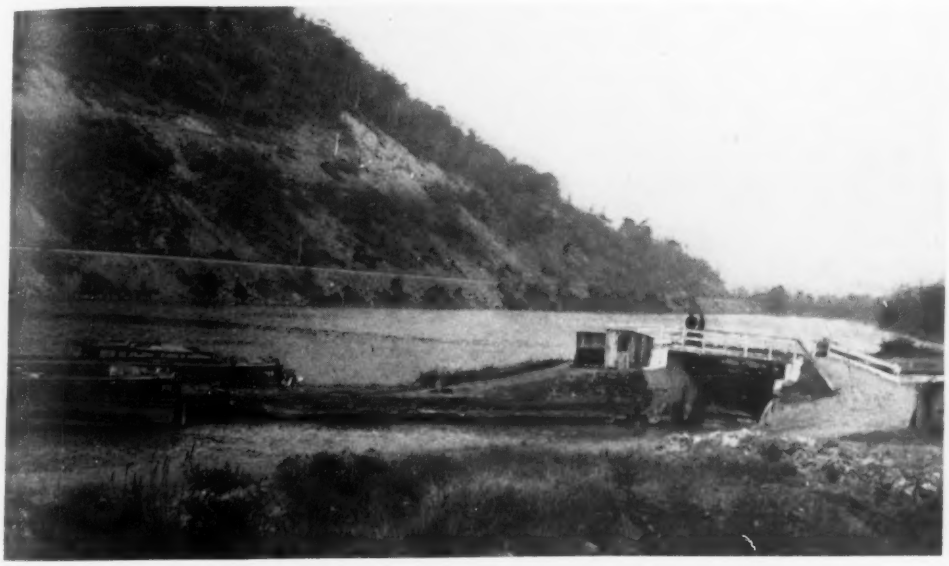


FIG. 11. ALONG THE LEHIGH CANAL

AT THE ENTRANCE TO THE LEHIGH WATER GAP. THIS IS THE LAST REMAINING CANAL FUNCTIONING IN EASTERN PENNSYLVANIA. THE SMALL CANAL BOATS TO THE LEFT HAUL "RIVER COAL" (DREDGED FROM THE BOTTOM OF THE STREAM) ALONG THE CANAL TO SUITABLE STORAGE PLACES. NOTE THE RAILROAD GRADES OF THE LEHIGH VALLEY (BELOW) AND THE LEHIGH AND NEW ENGLAND (ABOVE) ON THE OPPOSITE SHORE.

Lehigh Canal was begun in 1827. As far back as 1792 the Lehigh Coal Mine Co. had been organized to exploit the anthracite along the river beyond the Lehigh Water Gap. The industry met no success until Josiah White and Erskine Hazard took over the project of making the Lehigh navigable. A system using what were called "bear-trap gates" was adopted. This consisted of V-shaped dams across the streams. By such means artificial floods and high water could be created almost at will to carry the boats, coal-laden, down the river. The greatest development followed the organization of the Lehigh Coal and Navigation Co. in 1820. Canal construction began in 1825. Four years later the canal was opened. A succession of slack-water stretches of river alternated with lengths of canal (Fig. 13). Few passengers seem ever to have used the Lehigh Canal, but coal was for years sent down it in great quantities, 200,000 tons in 1837 alone. It is noteworthy that today (1942) the Lehigh is the one remaining trans-gap canal that still operates, but only locally to carry coal dredgings from the river to shore for storage. Like the Delaware and Hudson, the Lehigh Canal was connected with the mines by a gravity road. The famous Switch Back at Mauch Chunk, after it had ceased to carry coal, was equipped with passenger cars and supplied a thrill to our immediate ancestors of pre-automobile days.

Next in order westward is the Schuylkill Valley. The Schuylkill Navigation Co. operated a succession, partly canal, partly slack water with dams, to connect Philadelphia with the interior and eventually to tap the coalfields at Mount Carbon and Pottsville. Its original purpose was not primarily for coal transportation, as the value of anthracite as fuel was still doubted. Timber, agricultural products and other commodities were taken out over this line. In 1824,

four years after opening, the first coal boat to Philadelphia came down the Schuylkill Canal.

Along Swatara Creek in Lebanon County a canal was finished in 1830. It was actually a branch of the Union Canal completed in 1827–28, which tied together the Schuylkill and Susquehanna Valleys by way of the Lebanon Valley south of Kittatinny Mountain. This route gave a navigable feeder to the southern anthracite field by way of Pine Grove. The canal penetrated Kittatinny Mountain along the water gap of Swatara Creek and ended in a large reservoir a few miles above that feature. Never of much importance, this canal was nearly ruined by a flood in Civil War times. It never recovered from the blow.

The most important of all our eastern canals, as may be judged, was the already mentioned Pennsylvania Canal itself, which followed the Susquehanna and its principal tributary, the Juniata. This route was intended to connect Philadelphia with Pittsburgh. From the principal line a shorter branch edged the east side of the main valley of the Susquehanna to Millersburg to tap the anthracite fields from their west side. A branch canal and railroad tied it with the coal at Short Mountain. Another canal ran up the west bank of the Susquehanna to a point opposite Northumberland at the confluence of the West and North Branches of the river. Between the forks and the mouth of the Juniata several gaps were negotiated. At the confluence the canal divided. The branch to the east, known as the North Branch Canal, followed the North Branch of the Susquehanna and continued to the New York–Pennsylvania state line at Athens to connect with the Chemung and Chenango Canals of New York. The canal up the West Branch followed the river to Lockport and Lock Haven and a little beyond (Farrandsville) to gain admittance to the soft coal workings in the Allegheny Plateau. A branch swung southwestward from Lock Haven along Bald Eagle Creek Valley and through Milesburg Gap to Bellefonte. This line was operated by the Beech Creek and Bald Eagle Navigation Co.

The Main Line, or Central Division, of the Pennsylvania Canal was the most important of all our artificial water routes; it included the Portage Railroad. Passing through Harrisburg, the canal's course lay up the river to Duncans Island, whence it entered the valley of the Juniata. In this lower part of its course it traversed three large water gaps in Kittatinny, Second and Peters Mountains. The main line along the Juniata ran through Millerstown, Mexico, Mifflintown, Lewistown and Huntingdon to Hollidaysburg, where it connected with the Portage Railroad. It had been the original plan of the builders to tunnel the Allegheny escarpment, but the idea was abandoned in favor of the railroad. From the outset the canal had troubles. Opposition from teamsters did not add to the happiness of its builders. The main line had about twice as many locks as its rival, the Erie, and the Portage Railroad was a bottleneck. For these reasons the Pennsylvania Canal was not the keen competitor of the Erie that its sponsors had hoped. In fact, it is recorded that some Philadelphia merchants found it more economical and quicker to ship via the Erie than the Pennsylvania Canal. Necessity for speed was the downfall of this and many another canal. The Portage Railroad was closed in 1857, and the decade 1850–60 saw the end in general of canal-building in the eastern United States. The demise was synchronous with the railroad boom. The following figures from Harlow[1] show something of the extent of canal-building:

[1] Harlow, A. G., Old Towpaths, 1926, p. 403.

	Miles
Columbia, Hollidaysburg, Johnstown, Pittsburgh	276
Susquehanna Div., Duncans Island-Northumberland	40
North Br. Div., Northumberland-Wyalusing	124
West Br. Div., Northumberland-Farrandsville	75
Delaware Div., Bristol-Easton	60
Beaver Div., Ohio River to Newcastle, plus	31

The day of the canals with their roistering romanticism soon passed. At best they were deadly slow affairs, and the severity of Pennsylvania's winters and spring floods was enough to close them to operation for many weeks each year. It is little wonder that the new spreading railroads gradually acquired much of the freight and passenger business. Nevertheless, the canals did not immediately succumb. Even after the turn of the century some feeble signs of life showed on several. Today, except for the expiring gasps along the Lehigh, they are represented only by crumbling locks of caved-in stonework, weed-choked channels and the graceful curves of tree-grown embankments, still sweeping along many a valleyside. Paradoxically, be it noted that the uncompleted Harrisburg and Hamburg Railroad met its fate when the Pennsylvania Canal fell into disfavor. That railroad was planned as a feeder to carry produce from the back farms of Dauphin, Lebanon and Berks Counties out to the canal and the Susquehanna River. The railroad never turned a wheel.

As the old forts of French and Indian War days have left their stamp in place names, so too did the canals. Several are suggestive of the time when towns sprang up along the routes of the man-made

FIG. 12. SPRING FLOODS WERE A MENACE TO CANAL MAINTENANCE
DAMAGE DONE ALONG THE SUSQUEHANNA IN THE FLOOD OF 1936. DEBRIS AND RECEDING FLOOD WATERS ARE SHOWN ALONG THE ABANDONED CANAL NEAR DUNCANS ISLAND.

waterways. Among them are such names as Walnutport, Weissport, Port Clinton, Port Carbon, Port Trevorton, Beech Haven, Williamsport, Lock Haven and Lockport.

Parallel Bands of Steel

Conflict early marked competition between the Chesapeake and Ohio Canal and the Baltimore and Ohio Railroad. This friction characterized the growing war between canals and railroads. It was to end in the extinction of the one and the survival of the other. The canal no doubt had a certain advantage if not efficiency in handling nonperishable, bulky freight and goods that did not require speedy delivery. The winter's coal could be hauled in the summer. Nevertheless, canals were handicapped by the winter's freeze, and their slowness was their final nemesis. Owing primarily to year-round operation and greater speed, if to no other cause, the railroads won out over the canals.

If each year, from the 1830's on, one could have taken an aerial photograph of southeastern Pennsylvania, a comparison of these pictures would have shown railroad lines creeping westward and northwestward from Philadelphia. Prominent was the Philadelphia and Columbia Railroad, which connected the city with the Susquehanna Valley by way of Lancaster. From that place the Harrisburg Railroad chuffed north to the State Capital. From Harrisburg additional lines invaded the mountains along the well-tried routes of the Susquehanna and Juniata valleys. Almost from the start the picture has included the Pennsylvania Railroad advancing from Philadelphia to Pittsburgh. Built to fight canals and railroads to the south and to the north, it followed the line of, and competed with, the Pennsylvania Canal, up the Juniata and down the Conemaugh. The rails reached Lewistown in 1849, the foot of the Allegheny scarp in 1850. Communication over that feature was established two years later. Although the Portage Railroad struggled to maintain itself, it soon gave up the ghost. With it passed one of the most picturesque and, for its time, most progressive features of our early transportation system.

As with the canals, the railroads followed the lines of least resistance, the river valleys. They too made constant use of the gaps. Most of the Delaware Valley has been at one time or another used by railroads. The Erie Railroad follows its gorge from Port Jervis northwestward. The Delaware Water Gap (Fig. 1) has been traversed by two lines. The now abandoned New York, Susquehanna and Western track hugged the New Jersey side; the Delaware, Lackawanna and Western uses the Pennsylvania shore. After passing through the gap both roads used a smaller gap cut by Brodhead Creek through Godfrey Ridge. Leaving the Stroudsburgs, the lines climbed the face of the Pocono Plateau, a feat strictly analogous physiographically to the problem met by the Pennsylvania Railroad in ascending the Allegheny Front along its spectacular Horseshoe Curve.

Until the present decade the Lehigh and New England Railroad had a branch line through the Wind Gap (Fig. 2) from northern Northampton County to Saylorsburg, north of the Kittatinny Mountain. The line is gone, but special mention is made of it because in this specific instance use was made by a railroad not of a water gap but of a wind gap, *the* Wind Gap, in fact. Continuing west, the next important use of the gaps by rail lines is at the Lehigh. Today the Central Railroad of New Jersey, the Lehigh Valley Railroad and the Lehigh and New England Railroad all pass through Kittatinny Mountain at the water gap of the Lehigh River (Fig. 11). Additional use is made of gaps along this

FIG. 13. RAILROADS GRADUALLY DROVE THE CANALS OUT OF BUSINESS

VIEW ALONG THE LEHIGH TRACKS OF THE CENTRAL RAILROAD OF NEW JERSEY PARALLEL LOCK AND PART OF THE LEHIGH CANAL. AT THIS POINT A DAM CREATES THE SLACK WATER IN THE BACKGROUND. THE LOCK SERVES TO LIFT THE BOATS OVER THE DAM. THIS FRAGMENT OF CANAL IS STILL USED IN HANDLING "RIVER COAL."

FIG. 14. A RIBBON OF CONCRETE

ROADS LIKE THIS ONE CARRY THE AUTOMOBILE TRAFFIC OF TO-DAY THROUGH THE GAPS. VIEW ALONG U. S. ROUTE 309 ON THE WEST SIDE OF THE LEHIGH RIVER LEADING TO THE LEHIGH WATER GAP, WHICH IS LOCATED NORTH OF ALLENTOWN, PENNSYLVANIA.

river by the first and second of these railroads as they continue north through the ridges south of Mauch Chunk and beyond, into and across the anthracite fields.

Along the Schuylkill, railroads appeared early, for it was by this route that coal could be readily hauled to Philadelphia and tide water. The Reading Railroad (at that time, of course, the Philadelphia and Reading) ran a branch line from Reading to Pottsville. Not to be outdone, the Pennsylvania Railroad did likewise. Today both lines use the gap along the Schuylkill in negotiating the passage of Kittatinny Mountain into Carbon County. The Reading also maintains a line along Swatara Creek, employing the water gap on that stream through Kittatinny Mountain in northern Lebanon County. It is not necessary here to discuss numerous uses of gaps and stream valleys throughout the anthracite fields. In general, this region of highly folded rocks has yielded, through erosion, many parallel or converging ridges. Gaps a-plenty slash the mountains and have been of the utmost value in exporting coal from the area.

The Susquehanna Valley and its tributaries, particularly the Juniata, have from the beginning furnished important routes. We cited the advance of the Pennsylvania Railroad along this course. Let us examine its progress more particularly. Both the Pennsylvania and the old Northern Central railroads traversed gaps in Kittatinny, Little, Second and Peters Mountains north of Harrisburg. The Northern Central, now incorporated in the Pennsylvania System, then took the main valley from the confluence with the Juniata and pushed northward. A few gaps were encountered below Sunbury. There the Susquehanna, Bloomsburg and Berwick was built to enter the anthracite fields "from the back door." Tracks of the Pennsylvania System follow the West Branch of the Susquehanna into the northwestern corner of the state. In this it achieves what the canals failed to do. It avoids the difficult ascent of the Allegheny Plateau by using the entrenched river channel above Lock Haven. Coming down from the north to connect with the Pennsylvania near Lock Haven is a branch of the New York Central, noteworthy since it follows Pine Creek gorge in crossing the plateau. A passing mention may also be made of the utilization of the North Branch of the Susquehanna by the Lehigh Valley Railroad into New York State and of the fact that the Delaware and Hudson and the New York, Ontario and Western Railroads have access to the northern anthracite field by gaps in its northern mountain rim. Somewhat analogous to this is the situation encountered to the southwest about the Broad Top coal field in Huntingdon and Bedford Counties, where the Huntingdon and Broad Top Mountain from the west and the East Broad Top (narrow gauge) railroads enter this isolated area through gaps. In the case of the second line, tunneling is also used.

Where there were no gaps the railroads experienced difficulties. Notable in this regard is the Baltimore and Ohio. Between Cumberland and Wheeling eleven tunnels were drilled for this line. During the building of the Kingwood Tunnel, which occupied a full year, the cars were hauled over the mountain along a temporary, zigzag track. Perhaps because of the successful example set by the Baltimore and Ohio, it was proposed as early as 1840 to run a line across southern Pennsylvania from Philadelphia to Pittsburgh. Such a route would have required extensive tunnel construction. The original scheme was abandoned but was revived a generation or more later in the charter of the South Penn Railroad. A number of tunnels were actually started and much grading was completed before the line was abandoned. The unfinished road

was to have pierced a series of gapless mountains by way of Franklin, Fulton, Bedford and Somerset counties. Its route has recently suffered a belated reincarnation in that the old roadbed and unfinished tunnels have been taken over and to a large measure developed into the Pennsylvania Turnpike.

So, the railroads came to the gaps. East of the Susquehanna Valley their principal incentive was anthracite. Around it grew up that well-known group of camel-back-locomotive-using "hard coal roads." These included most of those mentioned. In the appropriation of the gaps the railroads went a step farther than the canals were able to do. Because of hill-climbing ability, rail lines overcame previously prohibitive grades. Where canals might come near to the mines, they were invariably dependent upon railroads or tramways of some sort from mine to boat. Contrasted to this, the railroads can load at the mines, then haul the coal through to its destination without suffering loss of time to reload. To this is added a year-round schedule impossible for the canal boat.

Electric street cars have nearly vanished from the interurban landscape. The days when we toured the country on "trolley rides" ended with the widespread use of the automobile. But while the trolley car was still at its best, lines occupied two of our major water gaps. The Stroudsburg, Water Gap and Portland Railway rattled along the highway on the Pennsylvania side of Delaware Water Gap. This line was obliged to zigzag over Godfrey Ridge south of Stroudsburg. The railroads had taken up all available space along Brodhead Creek. Compared with the steam locomotive, however, the trolley was as much better a hill climber as the steam line had advanced over the canal. The other gap used by an electric line was the Susquehanna. The Valley Railways Company operated along the west side of the Susquehanna from a point opposite Harrisburg to Marysville. This line was abandoned recently in favor of busses.

FIG. 15. HIGHWAYS ARE GREAT LEVELERS

IN THIS PICTURE STATE HIGHWAY 903 CLIMBS THE SOUTHWESTERN SCARP OF THE POCONO PLATEAU.

Gasoline and Concrete

The automobile far outdoes the railroad as a leveler of grades, even as the electric trolley was ahead of the steam line or the latter outdistanced the canal. Today a network of concrete and other hard-surfaced state and county roads crosses and recrosses our mountains. Yet, despite the apparent annihilation of all but the heaviest grades, many a highway still follows the long-established travel habits of its predecessors. They too use the gaps as the best means of reaching beyond the mountains. The following tabulation shows which gaps in Kittatinny Mountain alone are penetrated by present-day highways in Pennsylvania:

Gap	*Highway number*
Delaware Water Gap	U.S. 611
Wind Gap	Pa. 12, 115
Lehigh Water Gap	U.S. 309
Schuylkill Water Gap	U.S. 122
Swatara Water Gap	Pa. 72
Indiantown Water Gap	Pa. 443
Manada Water Gap	Pa. 894
Susquehanna Water Gap	U.S. 11, 14, 22
	Pa. 14
Sterretts (wind) Gap	Pa. 34
Doubling (wind) Gap	Pa. 233

Besides these routes there are others that disregard the gaps altogether or take advantage of mere low places in the crests. Notable examples along Kittatinny Mountain are Route 29, north from Lehigh County; Route 83, between Berks and Schuylkill Counties; and Route 274, southwestward from western Perry County. To cite other examples of highway use or nonuse of the gaps throughout Pennsylvania would take pages of detail. Merely, as a final remark, contrast the low-grade course of U.S. Route 22 (the old canal and rail route) up the Susquehanna and Juniata Valleys with that of U.S. Route 322 over the Seven Mountains. Yet, before leaving this topic, remember once more the construction of the Pennsylvania Turnpike. Remember that it developed the unfinished grade and tunnels of the defunct South Penn Railroad. It is significant as an example of low-grade, modern highway construction, which has refused to make use of the natural openings through the mountains for its course but boldly burrows through the ridges in a succession of seven tunnels. Our highways are arteries along which pleasure and commercial vehicles scurry. Use a "scenic route" across mountain ranges or plateau country of the central counties. Then turn east to the anthracite region. The busy line of coal trucks whirling back and forth is reminiscent of days when first the canal and then the railroad had "all the gravy" in this business. Already such roads used by passenger bus and van or truck are a serious menace to railroad revenue.

Wings over the Mountains

The highways indicate a partial emancipation of travel from mountain barriers. One might expect that air lines would be totally liberated from the influence of topographic features. Actually they are, yet did you ever notice, while driving along one of our major concrete highways that follows a river and cuts through gaps, huge figures sprawled across the pavement? They are route numbers, but obviously not put there for the information of the whizzing motorist. They serve as guides to the plane pilot. Even winged man tends roughly to follow the warpath of the pre-Columbian savage.

Further Military Aspects

The gaps influenced the savage in his migrations and raids. They figured in the French and Indian and in the Revolutionary Wars. They came back into the picture during the Civil War, indirectly, because such gap-using railroads as the Baltimore and Ohio and the Pennsylvania Railroad were important mili-

tary factors. The Civil War was the first major conflict in which railroads figured largely in the movement of troops and supplies. Occasionally the armies fought over these new and important military adjuncts. Yet, there were other more direct applications of the topographic features to the war than their use by railroad lines. What American school boy has not tingled as he read of the cavalry raids up and down the Shenandoah Valley? Bold horsemen invaded southern Pennsylvania, descending through gaps in more than one swift foray. How many are aware of the part

FIG. 16. A HIGHWAY THROUGH PENNSYLVANIA MOUNTAINS
OVER THE MOUNTAINS, RISING FROM THE GAPS IN THE DISTANCE, THIS HIGHWAY CROSSES THE RIDGE FROM WHICH THE PHOTOGRAPH WAS TAKEN.

that topography played in the Gettysburg campaign? Not the actual battlefield itself is meant. The geology and physiographic features of that area and their influence on the tide and outcome of the battle have been expounded. Notice, instead, certain other factors immediately preceding the decisive battle of the war.

General Lee's army was moving north in June of 1863. One of its immediate objectives in Pennsylvania was to take Harrisburg, important for two chief reasons. In those days, prior to the erection of the dam at the city, the broad but shallow Susquehanna was fordable during summer's low water. This meant a ready crossing. Harrisburg even in those days was a rail center. Trains pulled out to all four cardinal points. Control of Harrisburg meant a potential opening to strike Philadelphia, Baltimore and Washington from the west and north. Control of Harrisburg meant cutting the Pennsylvania Railroad at a vital point where it entered the mountains through a gap that could not be by-passed. Needless to say, the attempt was unsuccessful because of the advance of the Union troops from the east and southeast. Finally, regarding the Gettysburg campaign, on the eve of the battle a scouting or advance party of Confederates approached Sterretts Gap ten or twelve miles west of Harrisburg with the intent of taking this commanding position. However, finding that it was held by a strong force of Union men, the Southerners prudently withdrew. This wind gap, not Bloody Angle of Pickett's Charge at Gettysburg, is truly "the high-water mark of the Confederacy," if by that expression we mean

the most northern point attained by an armed body of its troops. For the last time in history, one of our gaps figured in war.

Geology through physiography and topography has influenced the development of our transportation system. It has been a factor in several wars. The rate of settlement was at first retarded by the mountains, then speeded by the use of water and wind gaps through those mountains. Travel routes have been affected from the earliest trails to the latest of modern devices for moving man and his goods.

In these days of uncertainty, with possible invasion by armed forces, attacks by land, by sea and from the air of our eastern shores, one is tempted to speculate upon possible future situations. Nay, such have even been anticipated, for it was partly with its military use in mind that the Pennsylvania Turnpike was constructed. Here a low-grade, hard-surfaced route is provided from the interior to the seaboard. Numerous exposed bridges and danger of damage from floods along other roads are obviated. Very real are such menaces along the old Susequehanna-Juniata Route (Fig. 12). By this new route, mechanized troops and supply trains can move across (actually, *through*) the mountains with speed and with a reasonable assurance of their safe arrival.

The lowland fringe of Europe has throughout history provided a relatively easy line of march for armies from Russia all the way around to the Pyrenees Mountains. At no point along this coast is an elevation in excess of, let us say, 200 meters encountered. A similar situation is present on our own coast below southern New England. But there the analogy ends. Mountains form no backdrop barrier separating coastal Europe from the interior. North America has this feature. Lateral movements north and south may not be hampered by heights of land. Movements westward are definitely hindered if not stopped. Given a sufficient force that is properly equipped to hold the gaps, our Appalachian Mountains still present a definite deterrent to an invading enemy. Yet who can say today what barrier will stand in staying military movements of an enemy with air superiority?

AGRICULTURE AND THE NATIONAL EMERGENCY*

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WHEN the Pilgrim Fathers landed at Plymouth, Massachusetts, in December, 1620, the 1900 million acres of land now constituting the United States of America was inhabited by some 800,000 Indians whose braves hunted, fished, and fought, while their squaws did the farming. Although the women grew corn and beans and stored the surplus for winter use, the redskins depended largely upon wild game, nuts and fruits for their food supply. Under their system of land use, each person had some 2400 acres at his disposal. Whether that large an acreage was required for his support, however, or whether population growth was limited by some other factor, is not known with certainty.

When, on another memorable December day 321 years later, Japan undertook to wrest some of our outlying possessions from us, a well-fed, complacent population of 133 million people, 170 times that of the original Indian tribes, was startled into action. For between Plymouth Rock and Pearl Harbor, agriculture, by the aid of industry, had so developed the land resources of this country that one acre was doing the work of more than 200 acres left to Nature, and doing it much more dependably. Now, with only fourteen acres of land per person,[1] our many millions are not only abundantly fed and clothed, but large surpluses of grain, meat and fiber are available for export.

Except for periods of war, the most difficult problem American farmers have ever faced has not been that of growing enough food and fiber to meet the needs of this Nation, but rather of finding an outlet for that portion of their produce for which we can find no economic use. The hunger that the Indians must have known and that many millions of Europeans and Asiatics are now enduring is entirely foreign to the experience of this proud land of plenty. Such food scarcity as certain groups of our people have suffered from time to time has been largely due to their very low earning power rather than to exorbitant costs of the products of the soil.[2]

It is apparent that agriculture involves something more than the mere acceptance and collection of the products of Nature. It consists in harnessing Nature to human needs. Sir John Lawes once defined it as "the artificial accumulation of certain constituents to be employed either as food for men or animals upon a space of ground incapable of supporting them in its natural state." The potentialities of food and fiber production in the United States, if the land as it now exists could be brought to its maximum agricultural productiveness, are enormously greater than most people realize.

The growing of more than adequate supplies of foodstuffs for our present population is normally so readily accomplished that it is almost unthinkable to us that anyone, any place in the world, should ever go to bed hungry. Like the

* Journal Series paper of the New Jersey Agricultural Experiment Station, Rutgers University, Department of Soil Chemistry and Microbiology.

[1] The density of the population of the United States is only about one-eighth that of Germany.

[2] Some 30 million of our people are ill fed, as measured by modern nutritional standards.

Goddess of Liberty adorning its ocean door, the United States of America extends a helping hand, overflowing with the choicest foods, to the starving peoples of all the earth. Even in this period of war, as ever greater demands are being made upon our granaries, the problem is not one of any lack of capacity of the land to produce more and more grain with which to refill them, but of a shortage of labor to harvest the grain, and a dearth of facilities with which to effect its world-wide distribution.

Yet in times like these one can not help wondering whether this war-time draining of our soil resources will not have to be paid for in the coin of a much greater expenditure of effort that, after the conflict is over, may be required to extract our living from the land. The question is: Has the Malthusian principle been permanently set aside, or will it return to plague even us when our war-impoverished population presses forward with an ever-increasing appetite for the products which the exhausted land no longer so readily supplies?[3]

It must be apparent, even to the city man whose only contact with the land is by way of the things he eats, that our soil has already lost much of its virgin fertility and that a larger and larger percentage of the elements now being removed from it by crops will have to be returned. In proportion as more of the farmer's after-the-war dollar must be reserved for the purchase of soil restoratives, less of it will be available for the buying of health, education, travel, conveniences, and the other refinements of modern life. The privilege of enjoying these semi-luxuries is what has distinguished the American farmer from the European peasant. Our larger farmers are lords in their own right, and a great many sons of American soil rise to positions of high attainment in industry, education and government. In contrast, the peasants of Europe are tied to the land, one generation after another, bearing an undue portion of the burdens of mankind upon their backs.

War, while it lasts, means wealth to farmers, for with war comes increased demand and higher prices for the things they have to sell. Although limits are placed upon selling prices of certain farm products, these limits are set sufficiently high to stimulate greatly increased production of those crops for which there is greatest need, an abundance of the necessary foods being the first essential in winning the war. It is to be expected, therefore, that farmers, whether moved by patriotic or mercenary motives, will do their utmost to make every acre count. But, in so doing, they are quite likely to neglect the care of the soil. That was our experience during the first World War and a very high price was subsequently paid for the very prodigal use to which the land had been put. Among the more spectacular consequences of this orgy of expansion of cropping acreages[4] across previously unbroken western sods was the development of an enormous Dust Bowl which spread like a cancer and was almost as difficult to bring under control. Many million acres of marginal land may again be brought under the plow if this war lasts several years longer. The rapid rise in the acreages of soybeans, peanuts, and flax, growing out of the necessity of producing oil to replace that normally imported from the Orient and the South Seas, shows one direction in which our farmers are now being encouraged to expand.[5]

[3] Some population specialists are of the opinion that our population curve may reach a peak at around 160 million.

[4] The area devoted to harvested crops was increased by some 40 million acres during the first World War.

[5] Increased acreages of any crop for which there is special need are obtained by guaranteeing minimum prices and by allotting more fertilizer, machinery, and labor to the farmers producing it.

When the American Continent was an Indian Paradise, its soil was securely sewed to the earth by the roots of grasses and trees that formed a cover over the whole continent. But once the white man stepped ashore and pointed his plow westward, the threads were broken and the soil, joining hands with the rain, began sliding down the slopes and rushing on out with the river waters into the sea. To make matters worse, the crops which the Indians cultivated and the pioneers quickly adopted are of such nature that, by growing larger and larger acreages of them, we have developed the most destructive type of agriculture the world has ever known.

Strange as it may now seem, the corn, tobacco, potatoes, beans, peanuts, pumpkins, and tomatoes which cover many millions of acres of land in this country were entirely unknown to the Old World before the discovery of America by the Admiral of the Ocean Sea. Our European ancestors on whom we had to draw for our knowledge of what to do with the land and when to do it had had no experience whatever with any of these crops, and only second-hand knowledge of the semi-tropical cotton crop, the popularity of which grew so rapidly in our warmer states that it soon became firmly entrenched as the "Queen of the South." The peculiar fact about all these plants is that not only must the land be plowed in preparation for them, but it must be kept free of weeds all summer long until they mature. Nearly 140 million acres of our finest farm land were being turned with the plowshare and planted to these clean-cultivated row crops, year after year, before anyone realized what disastrous effects their production was having on the staying powers of the soil.

When the situation became so appalling that even the blindest among us could see the handwriting of erosion on the sides of the slopes, far-reaching steps were taken by the federal government to bring our enormous soil losses under control. But already some 50 million acres of land had been permanently ruined for cropping purposes. And although our hastily devised methods of erosion control have been fairly effective,[6] the fact remains that our agricultural economy still needs to be redesigned around crops that are less destructive to the soil than are those which we inherited from the Indians. Now another war, by far the most devastating of all history, is upon us and the prospect of our ruining still more land again looms like a storm-cloud on the horizon.

What makes this problem so difficult to deal with is that our farmers, having been made machinery-minded by alert American engineers, have taken to power farming like the proverbial duck to water. Of all the devices which these inventive geniuses have perfected, none compares with the farm tractor in its power for evil, or good, depending upon how it is used. No sooner had the up-and-coming farmer's son laid his eyes on the tractor than he began the not-too-difficult task of inveigling his father into buying one. As a result, the number of tractors sold for farm use increased so rapidly that the 2000 manufactured in 1909 grew to 200,000 more efficient ones in 1920, and to a total of nearly two million fast-moving types in operation in the United States by the end of 1942.

Four highly important developments followed rapidly in the wake of the growing use of power machinery on American farms. The horse and mule population fell from 25 million in 1920 to 4 million twenty years later; some 50 million acres of land that had been tied to the earth by the root systems of the hay and pasture crops required to feed these work animals were released to the plow; thousands of miles of fences, which had had the effect of serving as Maginot lines

[6] A great deal of attention is now being given to the development of cropping and soil-management systems that do away with the necessity of frequent plowing of the land.

against soil erosion, were plowed up to make much longer fields for the convenience of the tractor; and the percentage of the people required to produce the necessary supplies of food for human and animal consumption was greatly reduced, the farm population remaining more or less stationary between 30 and 32 million, while the total population was growing from 105 to 135 million.

Whatever effects the present war may have on the economy of this country, it is difficult to conceive of any retreat of the successful farmer from his present position as an engineer sitting at the wheel of a mighty motor that races and roars across the fields, pushing down more fences, tearing up more sod, and cultivating more crops, day and night,[7] as long as more land is available. And it seems probable that, after the war is over, the young farm folks will still insist on using their usual allotment of motor power to speed to the distant city to see the same shows, dance to the same music, and sit at the same tables as the rest of the world. In fact, the war will tend to greatly further the interest of the farmer's sons in motorized equipment. Certainly, as soon as the last air battle has been won, the aviation-minded veteran will immediately set to work leveling off a landing field in preparation for the airplane that will be added to the long line of high-powered machinery on the old home place. Compared with the experience of those of us who were barefoot boys on the farm some 50 years ago, the farming of tomorrow can be made a glorious adventure in which one enjoys the luxury of independence without the drabness and drudgery that were once all too much a part of life on the land.

But as one studies the picture further he begins to be disturbed about the cost of equipping the modern farm with its many machines, and about the assembling of the larger acreages of land which must be acquired to keep this expensive equipment busy enough days of the year to make it pay its way. Profitable power farming means many more acres under one management and much higher intensity of farming. The great mass of farmers possess neither the funds to finance such a farming enterprise nor the skill to manage it, yet they will have to compete with those who have the capacity to make big business out of the growing of plants and animals.[8]

It seems important to point out that there are just as capable men in control of our better agricultural enterprises as manage our better organized manufacturing plants. The men who operate large farms successfully must possess the combined qualities of the artizan, the production engineer, the salesman and the executive. They must be able to adjust their operations to the vagaries of the weather. And they must know how to deal with living things that are subject to disease and death, in contrast with the relatively simple problem facing the manufacture of inanimate objects in a factory.

If one contents himself with an examination of the statistics of total production of the more important farm crops in the United States as a means of estimating whether or not all is well on the land, he finds little reason for alarm. Thus, the yearly production of corn since 1920 has been between 2½ and 3 billion bushels; of wheat, between 600 and 900 million bushels; of potatoes, between 300 and 400 million bushels; and of cotton, between 10 and 18 million bales, the fluctuations in production being determined largely by the weather and the anticipated selling price. Al-

[7] It is a highly significant fact that tractors are now equipped with headlights and are often operated all night long during the busier portions of the crop season.

[8] In many cases tenant farmers have been crowded off the land by the expanded operations of farmer-owners who, with their sons' help, are able to operate large tracts of land with a high degree of efficiency by the use of tractors.

though careful analysis shows that there was a steady decline in acre yields in the Corn, Wheat, and Cotton Belts from 1905 forward, reaching an alarmingly low level in the drouth years of 1934 and 1935, acre yields since that date have risen to new high levels of which those of the year 1942 were, very fortunately, the highest this country has ever known.

There is some doubt, however, whether these currently higher yields indicate definite upward trends from better land management or are mostly the result of more favorable seasons. If one considers the very marked improvements that have been made in agricultural machinery; the much better varieties of crops that are being grown; the much larger amounts of lime and fertilizer that are being used; the greatly improved technique that is being employed in the control of diseases and insects; and the great strides that have been taken in erosion control: he wonders why yields have not risen to much higher levels than the records show. For notwithstanding all that science has done to aid the farmer, the average acre yields in the United States are only 25 to 30 bushels of corn, 13 to 15 bushels of wheat; 100 to 120 bushels of potatoes; and 160 to 200 pounds of lint cotton. Every farm scientist knows that twice those averages can readily be produced. It is particularly distressing to note that the great State of Georgia, growing some 3½ million acres of corn, produces an average yield of only a little over 10 bushels of grain per acre.[9] In contrast, a capable farm boy in the neighboring State of North Carolina once grew 232 bushels of corn on one measured acre of land.

[9] The South is suffering the consequences of a lack of diversification of their agriculture, too large a percentage of the land being devoted to cotton and corn and too small an acreage to the small grain, hay, and pasture crops. Much of the land is bare of any type of cover crop during the winter months.

One of the most spectacular developments in agricultural production in the United States within recent years has been that arising from the breeding of hybrid corn as a result of which acre yields of this crop have been increased by an estimated fifteen per cent. over what they would have been with ordinary corn varieties. Yet plant breeding and selection, as applied to this crop, have been designed to take greater advantage of soil resources rather than to economize in the elements of fertility. Thus the yields of hybrid corn are higher than those of the ordinary strains because the roots of the hybrids are able to extract more nutrients from the soil. This means that the negative effects of indifferent soil-management practices are being compensated for by the positive effects of growing strains of plants that rob the soil more efficiently.

Developments in plant breeding must be associated with improvements in the technique of land management for continued success. This involves the withdrawal of highly erosive areas from cultivation; farming on the contour the parts that are plowed; employing cropping systems that reduce the necessity for plowing; conserving farm wastes and returning them to the land; and greatly increasing the consumption of lime and fertilizers.

In times of war, and of agricultural prosperity, some of these improved practices are put into effect on a large scale, but others are set aside as being more applicable to times of peace. Thus, the average grain farmer will endeavor to apply more lime and fertilizer during the war, but he will also plow more land and pay less attention to the control of erosion. Our hope lies in the possibility that the need for careful attention to our land resources was so forcibly brought to the attention of the people of this Nation as a result of the soil debacle of the last war that federal conservation agencies

will be permitted to function with ever-increasing effectiveness throughout the present conflict and afterwards.

There are many disturbing facts which will have to be kept in mind in dealing with the combined problems of soil conservation and land use in the United States as the years grow into centuries. Among these are the serious consequences of the alternating periods of agricultural prosperity and depression that are associated with wars;[10] the high percentage of tenant farmers of uncertain land tenure; the constant loss of resourceful farm boys and girls to the city; and the fact that the average small farmer is more and more poorly prepared to meet the competition of the well-financed and capable big-business type of individual operating a large and highly mechanized farming enterprise.[11]

What happens to the small farmer and the land he farms is a matter of considerable moment to all of us. And our interest is more than that involved in merely being assured that there will be plenty of low-priced food with which to fill this generation's stomach. It will be recalled that Oliver Goldsmith once voiced his concern with this subject when he wrote: "Princes and lords may flourish or may fade, a breath can make them as a breath has made, but a bold peasantry—the country's pride, when once destroyed can never be supplied." But Goldsmith had been born of an economic system of which peasantry was an integral part. It would never have occurred to him that peasantry, in itself, was a sign of national decadence.

The chief objective of farming, to the average farmer, is not that of accumulating wealth. In fact, there are very few wealthy farmers in the sense in which that term is normally used. Farming is a way of living. But it must be a way of living *well* if it is to play its part in the growing, developing, and educating of its share of the Nation's youth.[12] There is no location that is comparable to a prosperous farm as a place to be born. Yet in proportion as the small farmers are reduced to poverty and peasantry, too many farm youths will crowd into the industrial centers to their own disadvantage, and to the detriment of the Nation as a whole.

It is highly important that thoughtful men of both town and country stop to consider the net effects of war and its by-products on the peaceful pursuits of those who till the soil. The small farmer is no more inefficient than the small business man. He plays a useful part in the national economy. His costs of production may be higher than they should be but his contribution is more than mere farm produce. He represents a great stabilizing influence on the thinking of the Nation. And those of his sons who rise above the land to positions of great influence in the affairs of men carry their country philosophy into the councils of industry and government.

To avoid poverty and peasantry, some means must be provided for making the economic position of the small farmer more secure.[13] This may call for much more decentralization of industry which still, for no very good reason as of this day, tends to be huddled about the large cities. The more recent tendencies of some of the larger manufacturers to break up their production into smaller units and scatter them about the country needs legislative encouragement.[14] For such distribution not only permits of

[10] Prices of farm products fall sooner, and farther, and tend to stay down longer after the war is over than do those of other commodities.

[11] About one-third of our farmers consume as much or more than they produce and make little or no contribution to the Nation's food supply.

[12] Farm families constitute about one-fourth of the Nation's population but they supply about one-third of the Nation's youth.

[13] Some 3 million of our farm families are now living at distressingly low peasant-like standards.

[14] Some 25 million people classed as rural live in the country but are employed in the city.

bringing those city folks who desire it out into the country, but permits the farmer and his sons and daughters to add to their income by spending a portion of their time in the factory without leaving home. When depression again comes, as it most assuredly will, such farm folks can weather the storm much more securely than would have been possible had they been turned loose on city streets.

But our thoughts about farmers can not be divorced from our thinking of the soil of which they are the guardians. A nation's security is no greater than the fertility of its soil. So far, land owners, large or small, still assume that it is their privilege to do whatever they wish with the soil, and the law agrees as long as they do nothing to injure their neighbo[illegible]. But if we carry our thinking farther we come to the realization that it is also important that the land owner do no damage to the man who follows him in the ownership or tenantry of the land, whether that man be his son, his neighbor's son, or the son of someone still farther removed from the immediate locality. In due time we shall have to decide whether our farmers can be induced to care for their own and the nation's land by some system of subsidies that may be applied to the erodible areas, or whether they must be required to do it through some form of compulsory legislation.

In a democratic system of government such a problem normally resolves itself into the setting up, by legislative action, of a system of procedure whereby farmers can organize themselves into districts in which the best interests of all are permitted to set aside the unrestricted freedom of the few who fail to appreciate their obligation to that portion of the soil which, for their lifetime, happens to have been intrusted to their care. But there are large areas of land of low potentialities for crop production whose owners must be subsidized by the government, or the ownership must be transfered to the township, county, state, or nation. Such land has value for purposes that may be much more important than if it were used for the growing of corn, wheat, or cotton. For example, there is great need for the development of vast forest, recreational, and game preserves, in which a large amount of healthful, open-air work is involved. The farm folks of these areas who otherwise would have lived in penury may become partners in such a program to the advantage both of themselves and of the communities in which they live.

But philosophical considerations regarding agriculture must be ruthlessly shoved aside for the moment in order that we may concentrate our attention on the immediate problem of defending the freedoms for which we stand. Reduced to its bald necessities, our job is not only to win the war, but of seeing to it that our enemies produce a great deal less, and this applies to food as much as it does to munitions. For in the final analysis our enemies will lose the war because of the lack of food.

The currently spectacular military campaign in North Africa was undoubtedly undertaken for the purpose of establishing a base from which southern Europe could more readily be reached by air and sea. But when it succeeds it will have had the further highly important effect of not only shutting off large supplies of grain, meat, and potatoes but of phosphate rock as well. Previous to the present World War millions of tons of mineral phosphates were imported into Central Europe from Africa, America, and Russia every year. These phosphates, when transformed into superphosphates by the use of sulfuric acid, played a crucial part in crop production. Soon the only remaining sources of phosphate for the areas that are ringed by steel will be the basic slag, obtained in the refining of iron ores, and the bones of slaughtered animals,

and these will be far from adequate to meet their needs.

Some idea of the importance that has long been attached to the use of phosphatic fertilizers in Germany can be obtained from a quotation taken from the writings of Baron von Liebig, a world-famous German chemist of a century ago: "England," said he, "is robbing all the other countries of the condition of their fertility. Already in her eagerness for bones she has turned up the battlefields of Leipsig, of Waterloo, and of the Crimea; already from the catacombs of Sicily she has carried away the skeletons of many successive generations. Annually she removes from the shores of other countries to her own the fertilizer equivalent of three and one-half million men whom she takes from us the means of supporting and squanders down her sewers into the sea. Like a vampire she hangs upon the neck of Europe—nay of the entire world—and sucks the heartblood from nations without a thought of justice toward them, without a shadow of lasting advantage to herself."[15]

Germany is now in possession of the world's largest known supplies of fertilizer potash. She has developed the finest factories the world has ever known for pulling nitrogen from the air and putting it at the disposal both of her agriculture and of her army. But she has not been able to solve her phosphate problem. The hunger of the soils of the German-dominated nations for phosphates can no longer be satisfied and the result will be that crop yields will continue to diminish until this need can again be met. That will have to wait until the war is won.

Many millions of men, women, and children in Central Europe are now losing their lives not by being struck down by bullets but from the diseases that are associated with a lack of proper food. Unfortunately, we must add to their distress by making full use of all the means of withholding food, and the agents for its production, at our disposal. Yet, as soon as our armies have started their march to Berlin we must be prepared to supply food for all of the freed peoples as rapidly as they are released from enslavement. This is a truly gigantic task, both as to production and transportation, under conditions of war.

If the war continues for several years, it will be necessary to ration not only sugar, coffee, meat and milk in the United States, but most of the other articles we eat and wear as well. We would do well to give immediate attention to the question as to exactly how our manpower is to be distributed among the army, industry, commerce, and agriculture. Farmers are already short of labor, they are virtually unable to purchase new equipment, and they will soon be seriously handicapped for lack of rubber. Furthermore, the men who remain on the land will be getting older and less agile every year. And it must be kept in mind that there is no guarantee that the widespread good weather of 1942 will be repeated in 1943 and 1944.

Yet, whatever the handicaps and uncertainties, our farmers must not only feed ourselves, large numbers of our allies, and many millions of those who will be liberated from the Axis yoke, but they must build up a surplus to take care of the pressing after-the-war needs of many impoverished peoples that can not wait until another crop season has gone by. The more quickly we and our South American neighbors can make amends for the distress occasioned by the war and get the people of the devastated countries back to a semblance of normal living, the greater our likelihood of being able to avoid moral disaster, for the suspicions and hates that are lighted by

[15] Much of the present German philosophy of war has arisen from the resentment that has grown up as a result of the repetition of these and similar concepts.

wars are fanned into intense flame by hunger, pestilence, and poverty.[16]

But one important aftermath of the war which we can not ignore will be the much greater concern of all peoples for the necessities of life. As soon as the terms of peace have been signed the nations that rise up out of the ruins will immediately take thought of their land and the things that can be made to grow on it. Before many years have passed food surpluses rather than scarcities will again have developed. American farmers will once more be put through an economic wringer that may squeeze out more profit than was absorbed from the relatively high selling prices that now prevail.

Many maladjustments in agriculture will arise out of the expanded production of certain crops required for war use. The bottom will quickly drop out of the market for some of the war crops while the demand for others may grow because of new peace-time uses to which the latter may have been found adapted. War-made improvements in industrial processes may relegate some before-the-war crops to positions of much less prominence. Wood pulp, for example, may become a more active competitor with cotton, forcing the southern farmer into greater diversification to the detriment of the corn and hog men of Illinois and Iowa, and the dairy farmers of Wisconsin and New York.[17] On the other hand, corn, small grain, sugar beet, and potato surpluses may find an outlet in alcohol for use in the farm tractor, auto, airplane. It has been estimated, for example, that about 2 of Iowa's 10 million acres of corn would be required to feed the farm motors of that state.

But when the life-and-death scramble for a place under the agricultural sun again gets under way, many farmers will go down to defeat for no other reason than that of having a war-depleted soil. Yet the loss of fertility occasioned by the exportation of agricultural products, no matter how troublesome it may be, does not present a problem so insolvable as one might think, even though millions of tons of nitrogen, phosphorus, potassium, calcium, and other elements will thereby have been siphoned out of the soil and shipped abroad. By the time the war is over the capacity of the air-nitrogen plants in this country will have been enormously increased and when this nitrogen is no longer needed for explosives it can be put to work in crop production. Fortunately also, the United States has the earth's richest phosphate deposits, our known supplies of this precious rock totaling some 13 billion tons.[18] The potash problem, a serious one during the last World War, has been solved so effectively by our chemical engineers that we are now quite independent of the rest of the world for the salts of this element. Finally, there is no dearth of limestone, the use of which in adequate amounts to control the natural acidity of the soil solves the problem of any possible deficiency of calcium.

It may not be amiss in passing to direct attention to the fact that modern warfare would never have been possible on its present gigantic scale had it not been for the discovery and perfection of the means of taking nitrogen from the air by factory procedures. Yet when Sir William Crookes addressed the British Association for the Advancement of Science on this subject some forty years ago and pointed to the possibilities in the production of chemical nitrogen from the air, he was not thinking of war. In fact, his primary concern had to do with the wheat crop which, unless more nitrogen was forthcoming than was available

[16] The produce of some 80 million acres of land were exported from the United States to Europe annually for several years, beginning immediately after the armistice of the last war was signed.

[17] That portion of the rayon which is made entirely from wood now constitutes between 7 and 10 per cent. of our clothing materials.

[18] It is believed by some of our conservationists that, other than the soil itself, phosphate rock is by far the most important natural resource which this country possesses.

from the nitrate deposits of Chile, could not, in his opinion, be made to continue to yield enough grain to meet the needs of the wheat-eating peoples of the earth. It was Crooke's opinion that there was an important connection between the eating of wheat and the degree of civilization of a nation, the peoples who were fed on rye or rice never attaining to the highest culture.

But notwithstanding the contributions of the nitrogen of war to the arts of peace, the cost of replacing the elements of fertility which crops remove from the soil does become disturbingly large. Our yearly consumption of lime and fertilizers in the United States now amounts to some 25 million tons annually, costing farmers around 250 million dollars. And these tonnages, of necessity, must be enormously increased when the virgin fertility of the Corn Belt soils has been exhausted and the need for restoring their productivity becomes increasingly imperative. For example, the annual fertilizer consumption on the relatively new soils of Iowa, with 34 million acres of land in farms, is now only about 17,000 tons, whereas New Jersey, with a farm area one-eighteenth that of Iowa, consumes 184,000 tons of fertilizer per year. In other words, the rate of consumption of fertilizers per acre of farm land in New Jersey is over 200 times that in Iowa. When the time comes that the virgin fertility of the Iowa soil has been exhausted, and the farmers of that State have to apply the millions of tons of fertilizer its soil will require, a serious economic problem will have arrived "out where the tall corn grows."[19]

Yet fertilizer and liming costs, though high, are insignificant in comparison with those involved in bringing water- and wind-eroded soil back into production. In fact, about the only economic thing that can be done with badly gullied land is to let Nature, aided by the forester and the ecologist, take over the job of reclaiming it. This is a time-consuming process. Such enterprises are of the long-time, low-income type which normally are of interest only to governmental agencies.

It is conceivable, of course, that present agricultural procedures may, in due time, become as obsolete as has the forked-stick method of our far-distant forefathers for plowing the soil. There is no longer any question about our ability to grow plants without the use of the soil—and on a large scale.[20] But scientists are not content with that accomplishment. Careful search is now being made for the secret of the chlorophyll of green plants through which the sun's energy is translated into carbon compounds. There is reason to believe that, by microbiological and chemical procedures, we shall ultimately be able to synthesize every one of the organic compounds contained in plants and required by animals. Only the essential mineral elements would then have to be added to these synthetic products to yield complete foods. Such foods could be artificially flavored and colored, and they could even be molded into appropriate shapes to satisfy our aesthetic senses.

But with a world war waging it seems safer to depend upon the soil, and the crops that grow on it. And if we are to place our primary dependence there for many centuries to come, as we very probably shall have to do, it would be well to recognize that the "Good Earth" must be kept good both during and long after the war, and that the well-being of those who cultivate the land as well as of the land itself is a matter of concern to all of us. For the farmer is the modern Atlas on the strength of whose shoulders the security of the world, in surprisingly large part, depends.

[19] It would appear that the relative economic position of the farmers of the eastern states would be much improved when the virgin fertility of the Corn Belt soils has been exhausted and the farmers of that area are compelled to increase greatly their expenditures for soil-improving agents.

[20] It is possible that the solution-culture method of growing plants, using sand or gravel for standing room, may undergo considerable expansion after the war is over.

MAN'S LONG STORY

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We live in a time in which human values, built up slowly through centuries with untold sacrifice, are threatened with destruction; when nations at either end of the old world have set out on a career of world conquest with the intention of exploiting and enslaving the conquered peoples, and are pushing that aim with sub-human brutality; when our own country is fighting for its life. It is a time of fear and uncertainty. It is a time of human tragedy, when for millions the future is black indeed. Can science help us to an understanding of what has taken place, or give us a perspective with which to judge the present, or point to any hope for the future?

I

We need perspective, the perspective of a long past. Swept along in the rapids of present-day happenings, we are in no position to judge them. We need to stand on the bank, watch the river's rush, get some notion of its whence and whither. It were well to turn to the history, American history, European history of the last six millenniums. We have gone far since neolithic man started civilization on the flood plains of the Nile and in Mesopotamia. Other times have been worse than this, bad as it is. On the whole there has been advance.

We need a longer perspective even than that of the last six thousand years, a perspective that science alone can give. The master historian is the geologist; he deals with time on a scale which dwarfs ordinary history. To him, as to the Creator, a thousand years are but as yesterday when it is past and as a watch in the night. He speaks of a hundred million years with the same nonchalance that the ordinary historian displays in handling centuries; and if he misses by a million or even ten millions when he is talking big, he sees no need of apologizing.

That the earth is old, very old, has been known for the last two centuries, ever since the birth of geology as a science. But how old in years? Recently the discovery of radioactivity has led to a new and apparently reasonably accurate method of estimating geological time. Uranium by the loss of helium passes into lead. The rate of such loss has been determined in the laboratory. By comparing the amounts of uranium and uranium-derived lead in certain granites we can find the age of the granites, and a minimum age for the sedimentary rocks in which they have been intruded. Thus are obtained the data for the following table, which shows the periods into which the geologist divides the past history of the earth, with their respective lengths:

Period	Length	Length of time to beginning of (in millions of years)
Cenozoic (time of recent animal life)	60	60
Mesozoic (time of medieval animal life)	130	190
Paleozoic (time of ancient animal life)	300	490
Pre-paleozoic	1300	1790

These figures are approximations at best; still, we shall probably not go far wrong in fitting our thinking to this

schedule. It gives us some two billion years for the age of the earth as recorded in the rocks. Back of that is an indefinitely long, early planetary period of which the geologist has no record.

II

Time as mere duration is uninteresting. It is what happens in time that matters. The length of geological time has been emphasized not on its own account, but because probably during the whole of that time there has been life on the earth, slowly, very slowly developing into the variety which we see about us to-day. Time is the background for the story of life.

The ancestry of man is a long one. It goes back beyond Neanderthal man; beyond the ape, the early mammal, the fish; beyond whatever invertebrate ancestor the fish had; back to some single-celled form in pre-Paleozoic seas nearly two billion years ago. A long time for man to be at school. Progress has been slow, for Nature is a severe school mistress. Failure in her school means more than just waiting over a grade; the organism is thrown on the discard. She insists that her lessons be so learned that they become part and parcel of the organism, and she takes all the time necessary to secure that end.

Somewhere in the pre-Paleozoic sea existed single-celled ancestors of man, possibly like the ameoba. It could eat, assimilate, breathe, move, reproduce, all in very simple ways; but these were the essential functions of life. It was perfectly adapted to its environment; so perfectly that some of its descendants, still amoebae, are with us to-day. It was no newcomer into that early ocean; it had been at school for tens, perhaps hundreds of millions of years, and the lessons of that infantile grade had become a part of its very structure and function. We come along perhaps a thousand million years to the mid-Paleozoic, the Devonian, the age of fishes. Our ancestor is now a fish, admirably adapted to its medium, doing the same things the amoeba had been doing, but in a more elaborate way. And there were those millions of years of schooling between. Some of the Devonian fish, certain ganoids, were ready for a higher grade. In these the swim-bladder opened into the throat, and *in extremis* could be used for gulping air, that is, breathing. The fins were stout, and again, *in extremis* could be used for crude walking. Imagine these ganoids, caught season after season in time of drought in muddy pools on the Devonian flats, gulping air and floundering about, half in and half out of water. It was hard schooling, but some graduated; the air bladder developed into a lung, the fins into legs; and these ganoids were the ancestors of all the higher vertebrates. In the monotonous uniformity of the sea, evolution of the higher types of life would have been impossible; that required the variety of the land surface. The coming to land of these Devonian fish has been said to be "the most momentous step in the whole advance from amoeba to man."

Two hundred million years further down the line we are in the mid-Mesozoic. Great reptiles rule the air, the sea and the land. It looks as if their future were secure, that their reign would last forever. It did last for more than a hundred million years. But the future lay not with the reptilian giants, but with certain small primitive mammals, an offshoot of the line of reptiles. They had been waiting their chance for some tens of million years. At the beginning of the Cenozoic, Nature took them in hand for training for the higher grades; sixty million years of schooling it was to be. One group, the primates, came in for a special education of body and brain that had a more direct human trend. The early anthropoids, man's line, were tree-dwellers. Toward the middle of the

Cenozoic our direct progenitors came down out of the trees, adapted themselves to the ground, spread beyond the forests, and assumed an increasingly erect posture.

The Cenozoic was sixty million years long. Its last division, the Pleistocene or Glacial, was one million. Through this last period, which includes four glacial stages with long intervening interglacial epochs, man was slowly straightening up, increasing in brain capacity and intelligence, developing speech, inventing tools. His prolongation of infancy, far beyond that of other mammals, carried with it increasing teachableness, and the lengthening of the period in which offspring were dependent on their parents led to the beginning of the family with its accompanying intensification of the altruistic sentiments, to the growth of the qualities which we consider most distinctively human.

Early in the Pleistocene, forms recognized as man and not ape are found (Java, Peking and Piltdown man). Neanderthal man (*Homo neanderthalensis*) made his appearance in the last interglacial epoch; but it was not until the last glacial epoch, perhaps 50,000 years ago, that Cro-Magnon man appeared in western Europe, the first that is admitted to the present species (*Homo sapiens*), and whose descendants are doubtless with us to-day. Erect, with prominent chin, high forehead and brain as large as that of modern man, he was skilled in the use of simple tools, and his carvings and drawings and polychrome paintings are the admiration of anthropologists. Cro-Magnon man stands at a pivotal point in the world's history. He is the climax of two billion years of animal evolution. Man's long preliminary education is now completed. The stage is set for a new act in the drama of life; whether comedy or tragedy we do not yet know.

The purpose of this emphasis on the length of life on the earth is to show that the race enters manhood with an immense animal momentum. The Roman Catholic Church is said to hold that if it can have the teaching of its youth for the first seven years, it will guarantee them to the Church for life. Nature is man's teacher, and she has had his early education for a vastly longer time proportionally than the Catholic Church asks for its youth. Man has been in the distinctively human school less than a million years. He was in the primate (not primary) division throughout the Cenozoic, sixty times as long. He began his primary education as some single-celled form in the early pre-Cambrian ocean, possibly two thousand times as far back as the day when he was promoted to the human grade. Nature has insured that he learn his lesson well; that the animal is so inwrought in him that he can never get away from it. His human nature is a recently acquired and uncomfortably worn garment.

III

The first inference to be drawn from man's long animal inheritance is that he is primarily a creature of instinct. His driving forces are hunger, sex, fear, crowd, combativeness. No one who has honestly looked into himself or around at his neighbors can fail to see this. He is not a fallen angel, god-descended, mixed with animal clay. On the contrary he has risen from the animal level. Let us hope he is still rising, and has his eyes at times fixed on the stars. Unless we keep his animal origin and bias in mind, we can neither judge him fairly nor plan wisely for his future.

A second inference, indeed the obverse of the first, is that man is not a creature of reason. The zoologists when they named the human species called it *Homo sapiens;* man the wise! Whether they did this from egotism or wishful thinking or just for a joke, they were in error;

wisdom is not his outstanding characteristic. Reflective thought is a late acquisition and few have it in any large measure. The eighteenth and nineteenth century confidence in reason is now seen not to be justified by the reality. For most people, even for the best of us most of the time, reason is the servant of instinct, finding excuses for what one wants or has already decided to do. It is rationalization, first cousin of wishful thinking, which is not thinking; it is merely wishing. Here again honest introspection will give us the evidence; also observation of neighbors. If one wants proof in public life, he can follow the doings of the United States Senate, the resolutions of Chambers of Commerce, or the propaganda of nations at war. If he looks for it in the rarefied air of abstract thought, he can dip into any book on astrology or even theology.

However, man's being primarily a creature of instinct furnishes a needed conservative and conserving factor. His animal inheritance keeps him on the track, keeps him from going off into all kinds of wild disintegrating experiment. But had this been the only force at work, man would still be on the animal level; progress would be impossible. Sane human history is a balance between the conservative instinct we inherit from our animal ancestors, and the use of reason to guide that instinct.

Again, a clear appreciation of the strength of man's animal inheritance shows us that it serves to qualify both our hopes and our fears. It works against optimist and pessimist alike. The optimist expects that evil can be overcome, and that, speedily; that some sort of golden age or millennium is coming in the not distant future. The pessimist is sure that evil is with us to stay, and that to fight against it is a hopeless adventure. Both to the extreme hopes of the optimist and to the extreme fears of the pessimist the long biological-historical view is a corrective. The momentum of an age-long inheritance is not easily changed. The animal in us, often at odds with our idealism, will carry on indefinitely. But other forces are at work. We are told that we can not change human nature. But human nature can change. It has changed. We are what we are because it has. There is no good reason to suppose that it has ceased changing. But the process is extremely slow. Further, whatever may be said of human nature, human behavior can be changed, both in the individual and in the mass, and it is behavior that counts. Recent events in Germany may not be proof of any change in the human nature of the Germans; but they certainly bear witness to a change in German behavior; and it is German behavior that the rest of the world has to deal with. It is equally possible to shape human behavior to good ends.

IV

Organisms must adapt themselves to their environment as the very condition of survival. If a satisfactory adjustment has been achieved and then the environment changes, a new adjustment must be effected; and that is always difficult. The course of geological history is strewn with the relics of species that, failing in adjustment, perished. The application of this principle to man is this: man's body and mind reached its distinctly human stage in one type of environment, and he has lived on into a radically different type, which he has himself created, and he is having tremendous difficulty in making the necessary adjustment.

The environment of early man was that of forest, or forest and plains, suited to hunting; or, if he was near the sea, to hunting and fishing. It was an active life in the open. He needed neither golf course nor gymnasium. He got his food from plants that grew wild, or from ani-

mals of the chase; at any odd time, not thrice daily o' the clock. It was one continuous struggle against cold and hunger. Eternal watchfulness was necessary that he get the animal before the animal got him, for both were out for a meal. Strength of limb, keenness of eye and ear, accurate knowledge in a narrow field counted for more than familiarity with Plato or the calculus would have done. On them hung the issues of life and death. Dense population was impossible; there was not food enough. If population crowded on food supply, then war, starvation or infanticide kept it down. It was a life close to elemental nature, a life in which every normal adult could and did share somewhat equally, had his chance, and was on the whole equal to the situation.

All that is a matter of far away and long ago. Some thirty thousand years separate us from Cro-Magnon man. Two great environmental changes have taken place. The first, to a settled agriculture, we see already accomplished at the beginning of recorded history, some six or seven thousand years ago. Man at that time possessed domestic animals and cultivated grains; and on this basis he had established permanent agriculture on the rich, level, well-watered flood-plains of the old world. This permitted the accumulation of wealth, the growth of dense populations, commerce by land and sea, together with arts and industry, and the development of social classes. It permitted war, conquest and slavery. Still, the great mass of the people, the farmers or peasants, lived an out-door life not greatly different from that of the earliest hunters.

The second change, a revolutionary one, the greatest of all in man's environment, began some five hundred years ago. We find ourselves today in the very rush of it. Our age has been called, not wholly accurately, the age of science; the age of technology would be the better term. Technology has been slowly growing, as a process of trial and error, from the very earliest times. The pyramid builders in 3000 B.C. had a high degree of technical skill. Man has not been so stupid that he has not been able through the centuries to improve the old ways, to find both new things to do and new ways of doing them. Invention, quite apart from scientific research, has made great advances in the last two centuries. Mere enumeration is all that is necessary: iron and steel, fuels (coal and oil) for power, transportation, the factory, mass production; all this culminating in crowded peoples and overgrown cities. For a while industry and new-born theoretical science followed separate paths. There was nothing in the early experiments in electricity to suggest the gigantic electrical developments of today. Science was largely the experimenting of individuals working alone. Slowly it became clear that science could be of use in human affairs. It was first pity, then endure, then embrace. Governments began to see the advantages of subsidizing geological, agricultural and medical research. Today most large industrial corporations support their own research staffs. Science and big business have entered into partnership, and technology advances by leaps and bounds. It is reported that $235,000,000 were set aside by industry for scientific research in the United States in one depression year. Whether in the end this union of business and science will be for the world's good, it is too early to say. It has made possible mass production and the modern city. Following, as it has, the discovery of new continents, it has led to commercial rivalry, the exploitation of weaker peoples, the demand for new markets and new sources of raw materials, race antagonisms and world wars.

It goes without saying that man himself has produced this new environment.

Nature with no help from man shaped the environment in which he acquired his mind and body. But to a large degree he has taken over from Nature the building of his environment, has already tremendously changed it, with what results we are beginning to see. He must now work out his destiny in a world amazingly different from that of any epoch of the past.

This change to a technological environment is inevitably accompanied by maladjustments which reach into every aspect of life. The dwellings in which we live, whether the tenements and shacks of the poor or the air-conditioned apartments of the well-to-do, are a sharp contrast to the open-air life of man's formative period. The specialized and monotonous work of the miner or factory hand is slavery compared with that of the early hunter, which, if strenuous at times, lacked neither variety nor interest, and was a real education. The deep canyon-streets of the city, filled with noise, gas, dirt and rush, or the drab surroundings of the factory town, are a sorry alternative to the open country. Two views of lower Manhattan, taken more than three centuries apart, would symbolize the change. One, today, would show the wonderful sky-line of high buildings, the other the wooded island Hudson saw when he entered the upper bay in 1609.

The human element in the environment has changed no less than the material. The pace of modern life and the intellectual level on which it is carried on, make demands beyond any that were made on early men, demands which many can not meet. Modern industry finds many unemployable persons. It requires more from those it takes on, and scraps those it can not use with the same lack of consideration with which it scraps outworn machinery. It imitates Nature in her harsher moods.

The results? Before the war, between five and ten million unemployed in the United States, facing the choice between public support, starvation or crime; worse, unemployables; poverty, economic insecurity and recurrent depressions. Clearly the economic system is not working satisfactorily. Sickness: the medical bill of the United States is some three billions a year, and large numbers get no medical care. Defectives and insane: mental cases in hospitals rose from 63.7 per 100,000 in 1880 to 263.6 in 1934. The total annual cost of crime, direct and indirect, in our country runs into the billions. This tremendous load; unemployment, including the idle rich, crime, sickness, waste, class struggle, and worst insanity of all, war; all this is loaded on the backs of the actual workers on farm, in factory and office. This is the "white man's burden," not his egotistically assumed overlordship of races of another color.

V

What of the future? Physical conditions alone considered, there is every reason to believe that the earth will be a suitable home for men for a long time to come. And long here means long; tens of millions of years, perhaps hundreds of millions. There is nothing in the geological past to suggest any speedy wind-up of mundane affairs. If some wandering star approaches our sun and upsets things, or if the sun blows up, as suns (novae) have been known to do, or if in the far distant future our central sun becomes cold, that will end us. But such contingencies are almost infinitely remote, and the scientist, as a student of earth's history, is justified in ignoring them.

Climatic conditions will continue to be favorable. When the extent of the continental glaciers of the northern hemisphere was first appreciated, it seemed as if the earth might be cooling down; that

we were about to enter upon a long period of refrigeration, in which human life would become increasingly difficult, and finally end. We have since learned that glaciers are no new thing in the earth's history. There was extensive glaciation at sea-level in India, South Africa and South America at the end of the Paleozoic, perhaps two hundred million years ago. Another extensive glaciation occurred twice as far back, before the beginning of the Paleozoic. Climatic changes seem to have been rhythmic instead of progressive; swings from warm to cold, and back again; from wet to dry and dry to wet; but at all times of a character to permit human life, had it been in existence. There is no reason to suppose that conditions will not continue much the same in time to come. The weather prediction for the future is "favorable." Today's climate, like all weather everywhere, is "exceptional." We are still in the fag end of a glacial period, with immense ice-sheets in Greenland and Antarctica, and abundant mountain glaciation. There have been four glaciations in the Pleistocene. It is quite within the realm of the possible that another ice sheet may develop in Canada, push south into the United States, and overwhelm New York, Cleveland and Chicago; the last ice sheet reached that far. The next, if there is a next, may do the same. It will not be a glacial blitzkrieg, however. There will be plenty of notice in advance. And it will be exceptional. Through most of the past the climate has been mild and uniform, and it will probably be so through most of the future.

The surface of the earth has been the scene of an age-long battle between elemental forces. Century by century the rivers have been sweeping the debris of the land to the sea, and the rising sea has been creeping up over the borders of the continents. If these were the only agencies at work, the continents would be reduced to submarine platforms in the course of a few million years. But always, in the past, before that has happened, internal forces have raised the surface of the continents, and the rivers and the sea have had to start all over again. This rhythm of erosion and renewal by uplift has been going on since the beginning of geological time. There is no reason to suppose that it will not continue through an indefinite future. Man can not stop it, but he can adapt himself to it. In the distant future ocean waves may again wash the sites of New York and Chicago, Cleveland and St. Louis, as they have in the remote past; but there will be land somewhere, and the changes will come about so gradually that there will be abundant warning that moving day approaches.

The environmental aspects just mentioned are exempt from interference on the part of man. Others are not. Man cuts the forest, plows the grasslands, and plants his corn and wheat. He digs or drills the ground for his fuels and his metals. These are his resources for food, for industry. How is it faring with these natural resources?

First, as to the food supply. There will be enough to eat, if. . . . There have been times in the past when a land animal like man would not have found enough to eat, enough of the right kinds of food. When the lung fish of Devonian times came ashore to become the ancestor of vertebrate land life, he found an abundant vegetation. But it did not contain our present foods. None of the plants which fill the spring seed catalogues were then in existence. Flowering plants did not come until late in the Mesozoic, nor were grasses and grains, man's basic foods, abundant until the Cenozoic. But now they are with us. Nature has done her part. "Behold I have given you every herb yielding seed, which is upon the face of the earth, and every tree, in which is the fruit of a tree,

yielding seed; to you it shall be for food." What man is doing at improving this endowment is told in the splendid story of modern scientific agriculture.

But plants require soils; aye, there's the rub! We are waking to the fact that soils are being destroyed in this country at an alarming rate. They are being washed to sea by the rivers and blown away by the winds. Already from one quarter to all of the top soil has been eroded from 59 per cent. of the United States. They are being impoverished by cropping without any return of the essential elements taken. Soil loss is a serious national threat; soil conservation a great national problem and need. The soil is a resource which can be used and kept. Soil exhaustion is not necessary. Some soils have retained their fertility after thousands of years of use, but it has been intelligent use.

Resources such as soil and water, if properly handled, can be used and kept. With them you can eat your cake and have it too. It is different with most mineral resources. The fuels—coal, oil and gas—are stored supplies of organic origin which have come down from the geologic past. If they are forming anywhere today, it is at a rate which is infinitesimal in comparison with that with which they are being used up. The supplies of coal and oil are limited in amount, and when they are used up they are gone. There is a certain coal tonnage still in the earth. Its amount is fairly well known. How many years it will last depends on so many factors that no accurate forecast can be made. Those already made speak not of decades, nor millenniums, but of centuries. The story of every oil field is one of discovery and exploitation, followed by slow decline to exhaustion. There are a definite number of oil fields in existence. Some are known, others are yet to be discovered. When the last field has been discovered and exhausted the supply of petroleum will be gone forever. Then, unless something is invented to take its place, we shall be driven to the distillation of oil from oil shale.

Coal and oil are fossil sunlight, the sun's energy stored up by plants of the geological past. Plant life today is temporary storage of the sun's energy. It may be that before these supplies are exhausted our physicists and chemists may hit on some way of directly catching the sun's energy, that future housewives may can sunlight along with peaches and tomatoes for winter supply. Or will the Sunlight Company of America establish a monopoly?

Metals, too, occur in limited amounts. They are concentrations, mainly by underground waters, of elements that in their original condition were so scattered through the rocks of the earth's crust as to be valueless. This is an age of steel; but in order to make steel there are required, besides iron ore, nickel, manganese, chromium, vanadium and other alloy metals. These occur in small amounts and are widely distributed over the globe. In all, the supply, whether large or small, is definitely fixed in amount. Metals are a limited and exhaustible resource, and they demand the most careful conservation.

If we take the long view, there would seem to be but one conclusion that we can draw from the limited supply of mineral fuels and metals, and that is that there is a fixed period set to the age of iron and steel, as we now know it. A careful use of our mineral resources may prolong its life, perhaps for a few thousand years, and substitutes for the metals will help. But it looks as though in the end it may be necessary to return to conditions like those which preceded the nineteenth century. Doubtless some would look on such a change with resignation. They are asking whether the Sunday paper, movies and radio, battleships, tanks and planes, and much of the

rest of modern production, have really raised our cultural level. Were not many men in Shakespeare's day living as full lives as any of us now?

To sum up: Nature has done her share to insure a favoring home for man for an indefinitely long future. If things do not go well, he has but himself to blame.

VI

Will man himself change, in body or mind? And if so, in what direction? These are questions impossible to answer. There seems to have been no significant change in his body since the beginning of the historical period. But in considering his future we have to do with not thousands but millions of years; tens, possibly hundreds of millions. There was immense evolution along many mammalian lines during the sixty million years of the Cenozoic; great changes took place in the human stock during the last million, since the first glacial period.

In the past, forms often became narrowly specialized, well fitted to a particular environment; and when that environment changed they were unable to adapt themselves to the new conditions, and perished. Man is a generalized form, a sort of jack-of-all-trades. He can run, but not like the deer; climb, but not like the monkey; swim, but not like the fish; and he can fly. But he has what birds, beasts and fishes have not, fingers and a superior brain. He can think; and by thinking he has, with his unspecialized body and hands and with the tools his hands have made, devised means for beating each of the others at their own specialty. It is probable that man will continue much as he is now, using his intelligence to secure his adjustment and his continued life.

That man has advanced mentally during historic times might seem to be a good bet; but it is one that can not be collected on, since there is no way of establishing the facts. Certainly the eminence of the Greek intellectuals proves nothing. With all their ability the Greeks were unable to weld together the small Greek states and prevent their overthrow by Macedonia and Rome. And it is a fair inference that Newton, Darwin and Einstein, Shakespeare and Goethe, and those who are organizing the complex industrial life of to-day, are at least the equals of the glory that was, for a short time, Greece.

With man a great change has come in the evolutionary process. In the past, evolving forms have been quite unconscious of their own development. For man this is no longer true. He knows the long course he has come, he discovers the factors at work in his own heredity and environment, he can look into the future; and he is able in a degree to take control of and direct his own evolution. He is already directing the evolution of the animals that are useful to him; the rest he exterminates. What he has done in producing different breeds of cattle, swine, sheep and poultry, a visit to any state fair will show. After such a visit one may conclude that it is just as well, in view of his present ignorance, that man has not yet begun to experiment in this way on himself. But the possibility is there.

VII

Man's evolution now is primarily social and cultural. It has been going on since earliest man; its description is the burden of history. And in spite of the wails of the pessimists its progress has not been slight. So it will continue to be throughout the immediate future, say for the next ten or hundred millenniums. As in biological evolution, there is variation (by the introduction of new ideas), heredity (in the sense of transmission by tradition), and struggle for survival, both within and between groups. That struggle is everywhere present in current American life, and is now going on

on a world scale with furious intensity in the present war. As with biological evolution, cultural evolution has been mainly unconscious and altogether unplanned; but here, too, man has reached a stage when he could in a measure take it in charge.

One important aspect of social evolution is the development of consideration for others, of the idea of right and wrong, of morality. Animal nature is non-moral. The question of right and wrong does not exist when the wolf drags down the deer. Consideration for others began with the early family. The long period of human infancy, close-spaced births over the woman's bearing period of thirty years or so, held the family together. In such soil thought for others had a chance to grow. Man's susceptibility to the favorable or unfavorable opinion of others helped. As a result there has come that slow growth of sympathy for others which has raised the struggle for existence above the animal level. It is these and other distinctly human traits which make life worth while.

To the development of altruism there is one chief enemy, our increase in numbers. Man, like all other animals, tends to multiply beyond the means of subsistence. When there are more mouths to be filled than food to fill them, when there are more men than jobs, the fight for food and jobs begins. Self comes first. "Skin for skin, yea, all that a man hath will he give for his life." We are each of us conscious that there is a limit beyond which our sharing ceases. Bare necessity pushes aside sharing and brings back the struggle for existence to the jungle level.

Huxley in "Evolution and Ethics" has drawn a picture of a garden cut from a wilderness. The gardener clears out all except the chosen varieties, nor are these allowed to crowd. Plan, the gardener's will, replaces struggle. But to maintain this the gardener must remain on the job; if not, the wilderness creeps in and in a short time no trace of the garden is found. So with the higher values which man has evolved up through history. They have been built up with infinite care, and continued care is the price of their preservation.

VIII

What are some of the first steps that should be taken in planning for the future? The foremost need is a clear-cut human ideal, the envisaging of "the highest human values realizable on earth through human effort" (Max Otto). This comes close to the democratic ideal, namely the fullest development of the possibilities of every individual, both on his own account and for the service he can render the world, the state being guardian, not master or slave driver. Each man to have his chance. It means the end of race discrimination. The claim of superiority by Europeans over non-Europeans has done immense harm to both.

In giving content to this aim, science, that is, knowledge, must help. Science, some say, has brought us to the mess we are in. True, technology rests back on science, but science is not responsible for technology, nor is technology responsible for the uses made of it. For that we are all responsible, through our stupidity and selfishness. We need to know vastly more about man, his heredity, the effects of his environment, the way his mind works. Millions are spent for research in technology, for improving glass, rubber, corn and hogs; very little for the study of man himself. One sickens at the billions now necessarily given for war, all of which would be unneeded in a decently ordered society; and thinks what tremendous advances the wide use of a fraction of that wealth would bring about if devoted to the problem of man. Just one hundred years ago Longfellow wrote:

Were half the power that fills the world with terror,
Were half the wealth bestowed on camps and courts,
Given to redeem the human mind from error,
There were no need of arsenals or forts.

We must revamp our economic system. We have the resources for a decent life for all. Poverty is no longer a necessity; it is a curable disease, and it is our shame that it is still with us. Our resources must be used for the good of all and not for the profit of the few. We need a new commandment, "Thou shalt not waste!" And we need to put new content into that old one, "Thou shalt not steal." This reconstruction will have to be done on a world basis, for science and technology have so drawn the world together that what is harm to one is now hurt to all.

Education must help, but it must be an education fitted to our present needs, not one that is an inheritance from an alien and aristocratic past. It must be an education that fits for jobs, trains leaders and gives a satisfying philosophy of life. An education that makes it forever impossible for one to forget that all that he has comes to him not through his own efforts, but because of the sacrifices of those who have gone before; and that he is not only a citizen of a national state, but a member of a world society. Above all separate groups is mankind.

IX

Let us gather up the threads of the argument. Nature has provided bountifully for man for an indefinitely long future; has given him ground to stand on, food, shelter, resources of all kinds for an abundant life. She has given him a brain far and away ahead of any other of her creatures, which makes it possible for him to take charge of his own affairs. But man is stumbling. He has radically changed his environment, and is finding it passing hard to adjust himself to it. He has called spirits from the vast deep and they have come; but he has not learned how to control them.

He finds himself at the forks of the road. Shall he drift and drift to destruction, or shall he take the problem of his future in hand and solve it? There is no question but that he has the necessary intelligence. The mind that can weigh the infinitely distant stars and tell their make-up, that can track down the minute carriers of disease, read its own history in the rocks; that can dig the Panama Canal and dam the Columbia River at Grand Coulée; that can run great railway systems with the accuracy of a watch, and build and keep functioning cities like Chicago and New York, can solve its social problems when and if it decides to do so. It is ourselves and not our stars that are at fault if we do not.

PHYSICAL SCIENCE AND PHILOSOPHY[1]

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THE relations of science and philosophy are matters of lasting interest and concern to man. In times of peace, it is a noble expression of creative activity that leads us to turn our excess energies —away from the pursuit of easy pleasures—to the disinterested study of relations which underlie our understanding of reality. In times of war, when excess energies for serious study are no longer available, we can still refresh ourselves by turning aside to a brief contemplation of matters that once concerned us deeply, and—God willing—will concern us deeply once again. Renewed by this refreshment, we can then return in good heart to our immediate tasks in the struggle for that kind of a world where man will again have the energy, the freedom and the disposition for disinterested creative thought.

The title "Physical Science and Philosophy" is a very broad one which was assigned to this paper in order to fill a place in the symposium planned in the honor of Newton. Under that title, I should like to present certain modest philosophical reflections as to the nature of science, with illustrations drawn particularly from physics. In formulating these reflections, it will be taken as agreed that it is the business of the sciences—physics, chemistry, physiology, biology, and so on, each in its own field of concern—to undertake a systematic and intensive program for the discovery, correlation, control and prediction of the phenomena of nature. It will also be taken as agreed that it lies within the wider business of philosophy to examine the assumptions underlying the methods of the sciences, to present a coherent synthesis of the results of the separate sciences, to evaluate the grounds of knowledge itself, to set forth the differences between the beautiful and the ugly, to expound the principles of right and wrong, and, based on such considerations, to attempt an integrated view of reality as a whole.

In accordance with the character of its own limited range of activity, the methods and results of science—unlike certain of those of interest to philosophy—may all be characterized as objective and abstract. The methods and results of science are objective, since success in the discovery, correlation, control and prediction of the phenomena of nature is a matter upon which substantially common agreement can be obtained. The methods and results of science are abstract, in the first place, since science abstracts or selects out from the general considerations which men give to their experience only that kind of treatment which actually is objective; and in the second place, since each particular science abstracts out from the general field of science its own particular field for systematic and intensive study. I shall relate my proposed remarks on the nature of science to its objective and abstract character.

Let us first say something about the objectivity of science. The test of objectivity is that of common agreement and acceptance, and new scientific discoveries and principles achieve objectivity and are incorporated into the body of

[1] From the symposium on "Natural Philosophy" commemorating the 300th anniversary of Newton's birth which was to have been presented at the New York meeting of the American Association for the Advancement of Science.

science as they meet this test. To satisfy this test it would not be proper to demand absolutely universal agreement and acceptance, but only that of diligent and competent men who have made an unbiased examination of the matter in question. As most scientists sadly know, there is a lunatic fringe of men who use scientific jargon to say things that are untrue or foolish. Indeed, there is a tendency for members of this fringe to organize into definite cults, such as flourish in considerable number in the neighborhood of my home in Southern California. In addition, and much more serious, there can arise groups of mendacious men who purposely devise false sciences—for example, theories as to racial culture and superiority—with which to delude and control their fellow countrymen.

Under the circumstances there are, to be sure, some difficulties in applying the test of objectivity, and in deciding which are the diligent and competent men to be depended upon for the unbiased examination of matters in question. Nevertheless, these difficulties are held in check by two important factors. In the first place, most men are in fact sensible men, and when the diligent and competent scientist shows them a newly discovered phenomenon and teaches them how to control it, they can for themselves distinguish truth from falsehood. In the second place, the results of science have a compelling pragmatic and survival value which makes it perilous to deny them. When the leader of a small mountain cult, denying the principles of physiology, subjects his child to the bite of the rattlesnake, the ensuing disaster results for all to see. When a nation, denying what science can say about the culture of different peoples, believes in the divinity of its emperor and follows the lies of the manipulators that surround him, its folly will be demonstrated either by the swift processes of war or by the slow grinding of the mills of the gods.

As a consequence of these two factors, there are no permanent difficulties in obtaining substantially common agreement as to the facts and principles to be accepted by science, and the objectivity of science persists as its most highly valued attribute. It is indeed no mean achievement to employ methods and obtain results that must be approved by all men at their peril.

Before leaving this discussion of objectivity two remarks may be made with reference to the contrast between the complete objectivity of science and the incomplete objectivity of philosophy.

The first of these remarks has to do with a possible but fallacious criticism of philosophy by scientists. Impressed by the possibility and importance of obtaining results that must be agreed to by all, some scientists tend to regard it as a perverse frivolity that leads philosophers to include methods and results which are not objective. This, however, is an unfair reproach, since philosophy includes within its scope epistemological questions as to the grounds of knowledge, aesthetic questions as to what is beautiful, and ethical questions as to what is good, concerning which there is not, and to some extent there can not, be common agreement. This becomes especially clear in the field of ethics, where it is evident, at least from a practical point of view, that different men have different ideas as to what is good and bad—for example, the Nazis and ourselves. Discussion of the extent to which objectivity might also be achieved in such fields as aesthetics and ethics must be left for another time.

My second remark has to do with a possible but fallacious criticism of science by philosophers. The circumstance that men's philosophies may make use of methods and results which are subjective, while science can only include methods and results which are objective, might

lead some philosophers to the suspicion that there are certain whole fields of human experience which are barred from scientific investigation. This suspicion, however, is not correct. The true state of affairs is merely that in investigating such fields science confines itself to objective studies. Thus it is within the province of the scientist—for example the anthropologist—to investigate the systems of ethics actually held by different peoples, and indeed to study the consequences of holding different ethical views. The anthropologist steps out of his role of scientist, however, when he advocates—as it well may be desirable to have him do—one system of ethics rather than another. The fact that there are no fields of human experience which are barred from scientific investigation, is an important one, since there are many differences of opinion between men which are not due to actual differences in subjective point of view, but to incomplete understanding of the objective phenomena involved. Thus when men, who advocate different ethical practices, come together for discussion, they often find that some of their differences can be reconciled by a scientific examination of the consequences of those practices. Hence, even though science can not resolve fundamental subjective differences between men, it can make its own important objective contributions in any field of human interest.

Let us now turn to a consideration of the abstract character of science. It will of course be appreciated in this connection that all kinds of human thinking are in any case actually abstract, since it is beyond the power of the human mind to deal with all aspects of a situation at once; some parts have to be abstracted or selected out for immediate treatment, and other parts neglected or left for later consideration. With regard to this inevitability of abstraction, however, philosophy and science adopt a somewhat different point of view. Philosophy, on the one hand, tends to be depressed by the necessity for abstraction, is specially concerned with the distortion or error that may be introduced by the process of abstraction, is troubled by the partial view which results from abstract thought, and would like to present an integrated view of reality from which the harmful effects of abstraction have been eliminated. Science, on the other hand, tends to be exhilarated by the advantages which are gained by its own particular program of abstraction—these advantages being, of course, the general objectivity which is obtained by the focusing of science only on those aspects of any situation upon which common agreement can be reached, and the specificity and energy of attack which is obtained by the focusing of each particular science on its own special field of interest.

There are many interesting questions that could be discussed in connection with the methods by which science in general abstracts out from the situations which it considers, that which is objective. These might include rather immediate questions as to the reproducibility of experimental measurements, the effect of environment on experimental results, and the use of statistics in analyzing experimental data and more psychological questions as to the criteria for selecting diligent and competent scientists, the effect of personal bias on results, and the relation between the subjective origins and objective outcome of scientific experiments. I shall make some remarks only on the last of these questions as to origins and outcome. As a heading for these remarks, I shall take the title "The Scientist's Day—Subjective in the Morning, Objective at Night."

In the morning, the scientist leaves his home, goes to his laboratory, and shuts himself in—kissing his wife as he leaves, greeting his colleagues pleasantly as he arrives, and taking off his coat and buckling down to work as he closes the

door. In passing, we may note the subjective determinants of this early morning behavior: he kisses his wife to express regret for the coming day of separation, he pleasantly greets his colleagues to placate them for the apparatus he will swipe before night; and he buckles down to work to satisfy his intellectual curiosity, economic needs, ambition or some general urge to achieve. But our present concern lies in what determines the program of work that he undertakes. At least on the days of great discovery, he selects this program, —mind you—not to obtain objective results as rapidly as possible, but to satisfy his own subjective needs to test some hypothesis or to prove some theory.

The good physicist on entering his laboratory, and seeing his apparatus before him, does not say, "I shall diligently use this apparatus to make measurements of the kind for which it is fitted and obtain with dispatch objective values which can be commonly accepted." Rather, he says things such as the following: "I shall find out whether an electrostatic charge set into motion does have the properties of an electric current. I shall look for the effects which should result from the earth's motion through a stationary ether. I shall see if the electrons in a conducting metal do exhibit mechanical inertia. I shall look for the spatial orientation of atoms in an external field so astoundingly predicted by the quantum theory. I shall find out whether the neutrinos which have been postulated to conserve energy in radioactive transformations would also act so as to conserve momentum." The origin of such problems is a subjective one, and the great physicist is the man who has a feel for problems which are both significant and soluble.

At night, as the physicist walks home from his laboratory, he thinks over the doings of the day and questions the objective validity of his results. "Were those meter readings due to some leak in my circuits, or really caused by the motion of the charge on my rotating disk? Does that group of consistent interferometer readings actually mean a positive effect, or it is really properly explicable merely as a statistical fluctuation? Are those occasional wild galvanometer throws actually of significance, or really due to unimportant accidental causes? Were those lines on my plate merely an artifact, or really caused by silver atoms that have been deflected in the magnetic field and shown up by my process of development? Was that track in the cloud chamber a chance disturbance, or really an evidence of transfer of momentum?" On the basis of many such nightly reflections, that which has objective validity is finally abstracted out from the welter of subjective experience in which scientists as well as other human beings are immersed.

Let us now leave further discussion of the processes by which science in general selects or abstracts out that which is objective, and turn to a consideration of the circumstance that each particular science abstracts a particular kind of phenomena for its own field of special and intensive study. This is a matter of great interest, not only because the progress of science has been greatly affected by the resulting division of labor, but also because the structure of science and of the branches into which it is divided is dependent on the sets of abstractions that the different sciences do make.

At any given time, the actual structure of science is considerably affected by past historical accidents and is in a process of change as new phenomena are discovered, new concepts invented, or regrouping of existing concepts appears profitable. For example, at present it would seem to many that the old separation between physics and chemistry has now become an artificial one which is maintained as a result of unimportant historical accidents which have taught physicists to read meters and chemists to

look at test tubes, and that a consolidation of the two sciences should now be undertaken. Nevertheless, in spite of accident and change, there is a general principle, for organizing the sciences into a hierarchy in accordance with the levels of abstractions that they employ, which not only helps in understanding the structure of science at any given time, but also tends to give considerable stability and permanence to the structure itself.

The possibility of making such a hierarchy of the sciences we associate with the name of Comte. In setting it up we start with the sciences which abstract for their study the simplest and most general aspects of the world of phenomena and proceed to those which abstract more richly patterned and less general aspects. Thus we pass from mathematics, which concerns itself with few and simple things such as number and order, to physics which adds motion, mass, electricity and the structural particles of matter, then to chemistry, which adds chemical substance and chemical reaction, then to the biological sciences, which add genes, cells, organs and organisms—and finally to such complicated sciences as psychology and sociology, in which the abstractions to be preferred are still a matter of considerable uncertainty. We thus obtain a hierarchy of more and more complicated sciences. Since the earlier sciences in the list provide concepts and methods which continue to be used by the more complicated ones, we often speak of the earlier sciences as more fundamental than the later ones. We also often speak of the earlier sciences as being more abstract than the later ones, since the process of abstracting away from the total situation has been carried to a further extent.

In accordance with the character of such a hierarchy of the sciences, it is evident that the different sciences would abstract out for their particular study different aspects of one and the same external situation. To illustrate this, let us take the traditional guinea pig, or better yet, say a litter of four guinea pigs, three black and one white, and note the reactions of different scientists to this same external situation. The mathematician will be interested in the circumstance that he has a collection of three plus one identifiable objects which can be arranged in various sub-groups and orders. The physicist will be interested in the weights of the different guinea pigs, their accelerations when acted on by forces, and the electromagnetic phenomena associated with their colors. The chemist will concern himself with the chemical constitution of the pigments in their hair and the chemical reactions going on in the bowels of the pigs. The geneticist, as one kind of biologist, will be interested in the Mendelian distribution of the litter, with the genes for black pigmentation dominant over those for white. And finally, the animal psychologist will be interested in the overall behavior of the little beasties, for example their abilities to learn their way through mazes. As a single illustration of the fact that a given science in the hierarchy may make use of more fundamental ones, we note the frequent use of mathematical notions by the psychologist, for example in plotting his learning curves, and in analyzing the statistical reliability of his results.

Although the Comte principle for the organization of the sciences into a hierarchy is an important one and gives valid insight into the nature of science, we must not take it too solemnly. The principle has been logically useful in classifying the sciences rather than genetically important in determining the historical course of their development, which has not taken place in an orderly fashion from the simple to the complex by the inclusion of further aspects of reality. It is not the only principle needed in classifying the sciences, since at a given level of abstraction we may also wish to

introduce other distinctions—for example, between a basic science such as physics, which studies underlying principles, a descriptive science such as structural geology, which describes a class of concrete physical phenomena, an applied science, such as dynamic geology, which applies the principles of physics to the understanding of those phenomena, or an applied science, such as economic geology, which makes applications to industrial ends. Finally, it is evident that the Comte principle gives us no completely permanent classification of the sciences, but is a principle which is to be continuously reapplied to get new understanding as science develops.

The development of science results from two principle causes: the discovery of new phenomena, and the introduction of new explanations for known phenomena. I do not think that the Comte principle gives us any special insight into the sacred act of discovery, but it may be helpful in understanding the introduction of new explanations, which often consist in explaining, at least in part, the phenomena studied at one level of abstraction in terms of concepts introduced by a more fundamental science, at a lower level of abstraction.

As an example of this, we may consider the explanation of chemistry in terms of physics. At its own level of abstraction, chemistry investigated the phenomena of chemical substances, pure and mixed, elementary and compound, the phenomena such as solution, precipitation and fractionation by which substances could be mixed or separated, and the phenomena of the chemical reactions by which changes could be made from one set of substances to another. And to explain the results of its findings, chemistry found it profitable to suggest the hypothesis of the atomic and molecular constitution of matter. Following this —to give an oversimplified account— physics then came along and found it possible to subject the atoms and molecules suggested by the chemist to intensive study, and to show that these atoms and molecules were in turn composed of more fundamental particles which had attributes such as mass, linear and angular momentum, electric charge and magnetic moment—concepts with which the physicist was already familiar—and finally to show that all of these structures obeyed the laws of the new quantum mechanics. With the help of these findings, it then became possible to undertake an explanation of chemistry in terms of the concepts of the more fundamental science of physics. This explanation has turned out to be very satisfactory, quantitatively correct in simple cases that can be worked out in detail, and qualitatively illuminating in more complicated cases. Indeed, the explanation has been so satisfactory that we now tend to regard chemistry as being—at least in theory—a part of the group of sciences that we call physics.

In this connection, however, I should like to report remarks which have been made by two of my scientific colleagues. My friend, Frau Ehrenfest, the mathematician and physicist, once remarked that chemists had always hoped for an explanation of their science in terms of physics, but were unpleasantly astounded when the actual explanation involved elaborate structures obeying the complicated new quantum mechanics, instead of simple rigid atoms obeying the well known principles of classical mechanics. In line with this remark, chemists may be expected for a long time to continue the use of older modes of chemical thought and expression, resorting to fundamental explanations in terms of ultimate particles and quantum mechanics only on occasions when this will be specially helpful. My friend, Otto Stern, who started as a physical chemist and became a great physicist, has remarked to me that perhaps a new principle might some day turn up to be necessary for explaining the behavior of great

numbers of atoms such as take part in ordinary chemical reactions, for example, some sort of a magnified Pauli exclusion principle. If such a principle should be found, it might then seem sufficiently different from the known principles of physics so that we should again wish to reinstate chemistry as a theoretically separate science.

As another example of the explanation of one science in terms of a more fundamental one, I should like to take the case of thermodynamics and statistical mechanics. Here following the methods of Gibbs, it has proved possible, also when quantum phenomena are involved, to correlate the concepts of the temperature and entropy of a system, which thermodynamics has specially introduced on its own level of abstraction, with mechanical quantities which describe the statistical distribution of ensembles of systems of similar molecular constitution. This has led to a very satisfactory mechanical explanation of the phenomena of thermodynamics.

I should like to mention three features of this explanation which illustrate kinds of features that turn up in other cases. By making use of the hypothesis of molecular constitution, statistical mechanics finds it possible not only to explain the phenomena of thermodynamics, but also to explain other phenomena, having to do with the properties of matter and with the rates of physical chemical processes, which lie beyond the scope of thermodynamics. By not making use of the molecular hypothesis, thermodynamics places itself on a more immediate phenomenological basis than statistical mechanics, and for that reason still retains certain special merits as a theoretical method of treatment. Finally, even though we accept the greater fundamentality and power of statistical mechanics, we shall often wish to continue the use of the language of thermodynamics, when possible, because of its greater simplicity and familiarity.

There are, of course, other cases where at least a part of one science can be explained in terms of more fundamental ones. Thus parts of sociology can certainly be explained in terms of psychology, parts of psychology in terms of physiology, parts of physiology in terms of physics and chemistry, and parts of all the sciences in terms of mathematical relations. These possibilities are so frequent and important that we may well wonder where the process of explanation in terms of a more fundamental science will stop. Perhaps everything could be explained in terms of mathematics. You will remember the belief of the ancient mathematician Pythagoras that "all things are numbers," and you may recall conversations of your own, with more modern mathematicians, who sometimes seem quite arrogant in their claims as to the scope of mathematics.

In this connection, however, it appears to me that there really are natural limitations on the possibilities of explanation in terms of more fundamental sciences. Such a limitation arises whenever a truly new aspect of reality emerges for study as we pass through the Comte hierarchy from the more to the less abstract sciences. I should like to illustrate this by considering the passage from kinematics, to dynamics, to electrodynamics. In the science of kinematics, we consider the space-time behavior of massless bodies, on which we can impose such laws of motion as we desire. On passing to dynamics we add the ideas of the masses of the bodies and of forces acting on them in accordance with Newton's laws of motion, and it will not be possible to explain away the essence of these new ideas by any appeal to ideas already present in the more fundamental sciences of kinematics and mathematics. Finally, on passing to electrodynamics, we add the new idea of electric charges that may be placed on the moving bodies and determine the particular character of the forces that act thereon; and this

again adds a new idea which can not be explained away in terms of previous ones.

There are, I think, two reasons why we sometimes become confused as to the extent to which it might be possible to explain the less abstract sciences in terms of the more fundamental ones. In the first place, since each science in the Comte hierarchy has the findings of more fundamental sciences available for its use, it is often the case that parts of its field of interest can be handled on a more fundamental level. If we forget that there are other parts of the field which involve truly new aspects of reality which have not been present at the lower level, we may then come to the erroneous conclusion that everything could be handled by the methods of a more fundamental science. In the second place, an occasion for confusion may arise from the circumstance that two different methods of approach may have been originally introduced for studying the same new aspect of reality. When we later come to prefer one of these methods as more fundamental than the other, we may then be led to the erroneous conclusion that this is an example of a process of explaining sciences in terms of more fundamental ones to which there will be no limit. Thus in the case of chemistry we have the phenomenological approach which makes use of the concepts of chemical substance and chemical reaction and the theoretical approach which makes use of the concepts of atomic physics. And in the case of thermodynamic phenomena we have the phenomenological approach which is based on the second law of thermodynamics and the theoretical approach which is based on the statistical mechanical hypothesis of equal *a priori* probabilities for different molecular configurations. When in these cases we come to regard the theoretical approach as giving a fundamental explanation of the phenomenological approach, we must not regard this as evidence that the really new aspects under study could themselves be explained away in terms of something more fundamental yet.

As an interesting example of the kind of problems that arise when we consider the possibility of explanation at a more fundamental level, I should like to make some remarks on the old controversy as to the possibility of explaining biology in terms of physics and chemistry. This question often arouses a nearly vituperative interest. On the one hand, the extreme vitalists claim that the behavior of living matter contradicts the laws of physics and chemistry, and on the other hand the extreme mechanists claim that the behavior of living matter can be completely explained by the laws of physics and chemistry. I feel sure that the extreme vitalists are wrong, and think that the extreme mechanists very probably are. In the first connection, it seems evident, merely as a matter of definition, that the behavior of living matter can not possibly contradict the laws of physics and chemistry, since the apparent occurrence of such a contradiction, in any situation where such laws were applicable, would merely be taken as a sign that the laws had not yet been properly formulated, and they would forthwith be amended. In the second connection, it seems clear, even though the behavior of living matter can not contradict the laws of physics and chemistry, that this behavior might involve situations which were not completely explicable in terms of physics and chemistry, since laws of a kind that we would be willing to call physical-chemical could not be applied. For example, as emphasized by Bohr, situations might arise in which a proposed physical-chemical study of the behavior of living matter might involve such drastic treatment as to kill the matter and thus defeat the desired study. There is, of course, much in the behavior of living matter that can be explained in terms of physics and

chemistry, and it is my own feeling that for many decades longer the physical-chemical attack on biological phenomena will be highly profitable. It would seem to me presumptuous, however, to assert that this mode of attack would necessarily be all that will ever be needed for the scientific treatment of the behavior of living matter.

As another illustration, which to my mind shows very clearly the inappropriateness of assuming that phenomena at one level of abstraction can necessarily be completely treated at a lower level of abstraction, I wish to turn to the ancient problem of free will versus determinism. The particular setting of this problem, that I have in mind, is the one in which it is asserted that a man's actions are determined by the processes which go on in his brain, and that these processes are themselves determined by the behavior of the atoms and molecules in his brain, and that this behavior in turn is itself subject to the laws of physical science. On the one hand, in the older days of the classical mechanics, this picture was then taken as making it certain that a man can not have free will, since his acts could be predicted by applying the laws of physics to the configuration of atoms in his brains. On the other hand, in the newer days of quantum mechanics, this same picture has been taken as allowing a gratifying loophole for free will, since the Heisenberg uncertainty principle makes it impossible to predict the precise behavior of a system of atoms from a knowledge of its configuration. Indeed, the Heisenberg principle has sometimes been highly praised as bringing moral responsibility back into the world.

On first hearing such arguments as to the dependence of a man's psychological behavior on the physical behavior of the atoms in his brain, one is tempted to continue the discussion at the physical level of abstraction. Thus, in the case of the classical argument, it is sometimes regarded as important to point out that the complexity of the atomic structure of the brain is so great that the possibility of predicting its behavior is a theoretical rather than a practical one. And in the case of the quantum argument, it might seem pertinent to point out that free will and moral responsibility could hardly be assisted by a principle which requires the undetermined part of atomic behavior to take place in accordance with the laws of random chance.

On more mature reflection, however, it appears that both forms of the arguments as to the role of atomic behavior in the brain, in denying or in permitting free will, are based on a fallacious assumption that phenomena on the psychological level can be satisfactorily and completely treated on the physical level. As pointed out clearly by Bohr, such arguments are really quite meaningless, since no experimental test would be feasible to determine whether the atoms in a man's brain are following either the classical or the quantum laws of mechanics when the man reports that he is acting with freedom of will. The test itself would have to be so drastic as to destroy both the man's brain and the feeling of freedom of will which is an essential part of the experiment.

I am very content with this clarification which Bohr has brought to one aspect of the old problem of free will and determinism, and wish to close with it as a final example of the usefulness of the concept of levels of abstraction. You will note that this example, with which I bring my simple remarks on the nature of science to their end, is one which emphasizes the circumstance that the discipline of physics, beloved and dignified though it be, is neither the whole of science nor the whole of philosophy. And with this conclusion, paying all due regard to my great affection and respect for physics, I find myself at peace.

BOOKS ON SCIENCE

GENETICAL EXPOSURE OF THE "RACE" MYTH[1]

A CONSIDERABLE flood of books on the subject of race in *Homo sapiens* has appeared in the last several years. Some of these have come from the hands of sociologists and anthropologists, and at least once or twice a geneticist has couched his lance at the ugly head of the Nazi myth. If one recognizes a new spirit of knight-errantry in these efforts, of which the present volume is one of the most recent, it is nonetheless gratifying that not all of our knights cut the figure of a Don Quixote on a worn-out Rosinante, but that a number handle sharp and flashing weapons with considerable adroitness, and bestride fresh and vigorous chargers. Professor Dahlberg, in spite of translator Hogben's enthusiastic remark that he is "one of the six living people who know most about heredity," is not above revealing an occasional chink in his armor. Or perhaps this is but haste and carelessness on the part of Squire Sancho, who admits that he converted the book from the native tongue of its author in a brief fortnight of enforced delay in Sweden as he fled from the enemy then engaged in occupying neighboring Norway.

This book, in brief, is not a comparison of the physical or cultural differences between so-called races, but is a consideration of those principles involved in race-formation. The first five chapters deal with standard genetic principles. Every geneticist will agree that a sound knowledge of these is essential to an understanding of the true nature of race. Unfortunately, one is all too often left with the feeling that the relationship of the topics to the main theme is not made apparent. The author seems to drift into a presentation of a survey of genetics as a field of knowledge instead of providing a selection of those genetic principles that bear critically on the nature of races in man and of making that relation unmistakable.

The exposition is as a rule clear and simple, but the opening chapters particularly are marred by occasional statements or figures sure to be misleading and confusing to a lay reader. Some of these should perhaps be enumerated. Any Drosophila worker would be surprised at the legend to Fig. 16, where a normal fly with wings still unexpanded is said to represent the mutant "vestigial," while in addition two bristles always present in normal flies are said to be produced only through the action of the same mutant gene. Figs. 33 and 34 are hopelessly confusing. They fit the text discussion very well, but the legends refer to crossing over between yellow body color and white eye color, which the figures were certainly never intended to illustrate, rather than to simple sex-linkage, which they do illustrate. In the absence of any explanation, an inexperienced reader might easily be led to think the symbol *Y* stood for yellow body color, as *w* stands for white eye color, and that consequently yellow body color is limited to the male and transmitted by a chromosome limited to that sex. On p. 114, the statement that "among intersexual females development at first goes in the male and afterwards in the female direction" is a confusing slip directly contradictory to Fig. 36 and the succeeding discussion. Worker bees (sterile females) are said to be intersexes (p. 115)! The statement (p. 119) that "genes are chemical constituents which react with one another" is subject to grave misinterpretation, and the remark (p. 120) that "all genes which influence size and form may be said to

[1] *Race, Reason and Rubbish.* Gunnar Dahlberg. Translated by Lancelot Hogben. Illustrated. 240 pp. $2.25. November, 1942. Columbia University Press.

speed up or slow down cell division" is certainly far from true for either plants or animals. An incomplete sentence at the top of p. 139 will undoubtedly make the reader scratch his head. On pp. 142 and 143 there are several mistakes in simple mathematics that will be obvious to those who already know how to calculate gene frequencies, but that may completely disconcert the uninitiated reader just skilfully introduced by Professor Dahlberg to the elements of population genetics. To correct any possible misimpression at once, however, let it be understood that these marks of carelessness and haste in the preparation of the manuscript do not, in the mind of this reviewer, keep the book from being an exceedingly valuable contribution to writings in this field.

With Chapters V, on the relation of environment to gene exhibition, and VI, on the principle of random mating, the author gets fully into his subject. The practical problem of determining the genetic portion of variability, of defining the limits within which "individuals with a particular gene equipment can vary under the influence of different external circumstances," to use his own words, comes up first. Genetic, environmental, and conditional characters are distinguished, and it is pointed out that there are no sharp boundaries between them.

The relationship between the frequencies of dominant and recessive characters, on the one hand, and of the genes that differentiate them, on the other, is presented in a simple and graphic manner. It is easy to appreciate the significance of such conclusions, as that as a recessive gene becomes rare, the proportion of individuals carrying the gene in a latent manner must increase in respect to those manifesting the character.

The effect of selection against undesirable characters is also treated graphically and without recourse to the mathematics that usually makes discussions of this subject difficult for the layman. One chart (p. 150), showing the frequency of a recessive character in successive generations when all recessives in each generation are prevented from having children, is worth volumes. The general conclusions are not very heartening to those eugenists who favor radical measures of sterilization or segregation, for while selection against common recessives would produce a rapid diminution in their frequency, there are practically no detrimental recessives that are common, that is, with a frequency above five per cent.; while on the other hand, adverse selection would have a wholly negligible effect on recessive characters that are rare, and most detrimental recessives are indeed rare. To be sure, there are a few simple dominant conditions against which selection would be immediately effective, but over against these are numerous characters inherited in more complex ways, against which selection is even less effective in bringing about elimination than it is with simple recessives. It is in any case comforting to know that if rare defects can not be stamped out, neither can advantageous characters that are rare and inherited in a complex fashion—high intelligence, for example.

In considering the effect of inbreeding and assortative mating upon the incidence of inherited characters, the discussion is both clear and original. The conclusion is that "if a recessive trait is common, a greater or smaller amount of inbreeding makes little difference to its occurrence. . . . If it is extremely rare, inbreeding can greatly increase the occurrence of the character, but because the latter is extremely rare, a *relative* increase has no appreciable mass effect. . . . In real life we may have to deal with large population groups. . . where really rare genes occur, but if so there are relatively few cousin marriages. . . . If we are concerned with a

small one, many cousin marriages occur, but in a small community no gene can remain really rare." "For the time being, in many quarters, inclination to apply the results of race biology in practical policy is too strong rather than too weak. People do not demand the certainty which they ought to seek before they undertake thorough-going reforms."

The three final chapters develop the concept of "isolates," groups within which marriage is more or less a matter of chance. These may be geographical, but no less important are social, or class, isolates, and those of certain so-called "races," such as the Jews. The average size of the isolate in western Europe is estimated at 500 potential mates per individual. Of course, isolates vary enormously in size, and are constantly in flux. In Europe they have been breaking down and merging in recent times. As a consequence, the frequency of rare recessive hereditary characters has considerably diminished. Although the responsible genes are themselves no less abundant than formerly, most of them are latent in normal (heterozygous) carriers. On the other hand, characters that depend on the multiple action of dominant genes are enhanced by the break-up of isolates. There is evidence that average stature has increased in Sweden from this reason, rather than, as is generally supposed, wholly from an improvement in standards of living. Perhaps there is room for hope that intelligence may react similarly.

"Whatever may be said of isolates in general applies to races in particular." For inasmuch as "biologists do not speak of two races in nature unless each group actually has some territory where interbreeding does not occur appreciably, . . . a race . . . must be an isolate or group of isolates." Since migration and interbreeding have been so extensive in Europe, and since inherited characters show little or no correlation after a few generations of interbreeding, there is really no ground for assuming racial differences among European peoples. Europe has been as great a melting-pot of peoples as America. It is quite as likely that any blond Nordic type is produced by segregation and recombination from a racial mixture as it is that there was ever a pure Nordic component of the mixture to start with.

The chapter on the Jews is more than an apt illustration of the views of a geneticist on race. It is an eloquent commentary on the prejudice equally of our own and of earlier times that ever seeks to clothe itself in the guise of the greatest moral or intellectual force of its day, whether that be religion or science.

H. B. GLASS

DESCRIPTIVE HUMAN PHYSIOLOGY[1]

THIS book is a tragedy. It could have been, as the publisher's blurb says it is, without doubt, "the most easily comprehensible, the most complete, and the most fascinating work in its field ever offered to the general reader." Alas, one must add: it is dogmatic, inaccurate, superficial, in the way that the life sciences of the start of the century are superficial today, and often grossly misleading. There are hundreds of pictures, mostly beautiful and ingeneous ones. These are almost all that is claimed for them, except that they are a valuable contribution to biological teaching materials. But why did the author, who drew many with enormous pains and great skill, allow unnecessary errors and false implications to enter a number of them. In one on the metabolism of fat (p. 351), for example, the fatty acid molecule is represented as a watch chain of CH_2 links with a watch (CH_3) at one end and a small medallion (COOH) at the other. Why not make the polar group the big

[1] *Man in Structure and Function.* 2 volumes. Fritz Kahn. li + 742 pp. $10.00 April, 1943. Alfred A. Knopf.

watch and the CH_3 the little medallion? But this is a picayune criticism. More serious: an enzyme, as a chisel, degrades the molecule by knocking out links—single links and from the middle of the chain. The drawing is excellent; the analogy, effective; the facts taught, half truths. It would have been as easy to tell the whole truth and have two links at a time knocked from the end. It is this aura of positive half-truths that dims the book's value.

The pictures are, on the whole, excellent, and as descriptive anatomy the two volumes are useful. It is man's function which is butchered—by the text. Innumerable statements appear—flat unqualified factual pronouncements, often clothed in impressive quantitative garb—which must make any biologist squirm. Here are a few examples from the first fifty pages: "Protoplasm is a chemical compound . . ."; "These salts [in protoplasm] have a large number of functions; for example, they conduct electric currents and are consequently the bearers of electrical energy in protoplasm"; "In the molecule of the blood pigment 16,669 atoms are united . . .": "[Human chromosomes] certainly contain 10,000 times as many genes as those of the simple fruit fly . . ."; "For the generation of a human being 225 million sperm cells line up . . ."; "Through the terminal openings of the lymph-vessels flows the abdominal fluid, which moistens the pelvic organs . . ."; "Each connective-tissue fibre in our skin is a minute but independent vital unit that 'wants' to breathe, eat, rest, and exercise daily in order to remain healthy." But they continue through the book: "an exhausted human being can be restored to full working efficiency immediately through the administration of fresh blood or the serum of a rested body." (p. 133); "Chlorophyll itself contains magnesium instead of iron, but it attracts iron compounds from the soil." (p. 212); "Amino acid $\times 3$ = peptone $\times 3$ = albumose $\times 3$ = protein." (p. 286); ". . . the human body has hundreds, perhaps even thousands of nerve fibres, . . ." (p. 471).

But even this is not the worst failing of the book. The presentation of human biology is, in the main, correct. But it is dogmatic, barrenly categorical and descriptive, and written from the view-point of the physiology of thirty years ago with a few modern facts added. The author gets almost poetic about the "profound internal laws of harmony" which regulate body proportions. But his ponderous statement that the human body is a walking tower of three stories," . . . the skull; in it live the organs of the outer germ layer, the brain and many of the sense organs . . . the chest; here lives the central organ of the middle germ layer, the heart, together with the middle portion of the skeleton . . . the abdomen; in it resides the organ system of the inner germ layer, the digestive apparatus," irresistably reminds me of the school boy's famous essay on the same subject: "The body consists of the head, the chest, and the stomach. The head contains the eyes, ears, nose, mouth, and brains, if any. The chest contains the heart, lungs, and part of the liver. The stomach contains the bowels, of which there are five; a,e,i,o,u, and sometimes y and w."

The book will probably be a great success—lovely pictures, positive answers to the sort of questions laymen are wont to ask, an aggressive promotion—almost insure it. But the lay reader will be entertained more than instructed. He will accumulate phrases and facts (not all correct) more than understanding and insight. As I wrote some years ago on science popularization, "The reader of such news items is only concerned, or at least the writer of them assumes he is concerned, with enjoying a gentle tingling of his imagination, a sort of mental Turkish bath. Active exercise of his intelligence, to appreciate the significance

of or principles behind a real scientific development, is neither expected nor aided."

"Man in Structure and Function" will not help to bring science to the people, only scientism: that is the tragedy, for the book has so much of excellence in it that it could have humanized a science and educated the people. Instead it erupts dogmatic statements garnished with pretty pictures.

R. W. GERARD

THE NATURE AND HISTORY OF HURRICANES[1]

In the run of daily weather, we forget what great storms can do, and we are inclined to go about our daily tasks without thought of the dangers. Mr. Tannehill vividly, yet dispassionately, describes the winds and storm waves of hurricanes, the origins and tracks of West Indian hurricanes, the rainfalls and barometric pressures, the signs of approaching storms, unusual hurricane movements, and the frequency and destructive effects of these terrific storms. The reader is then in a very receptive mood for the chapter on precautionary measures.

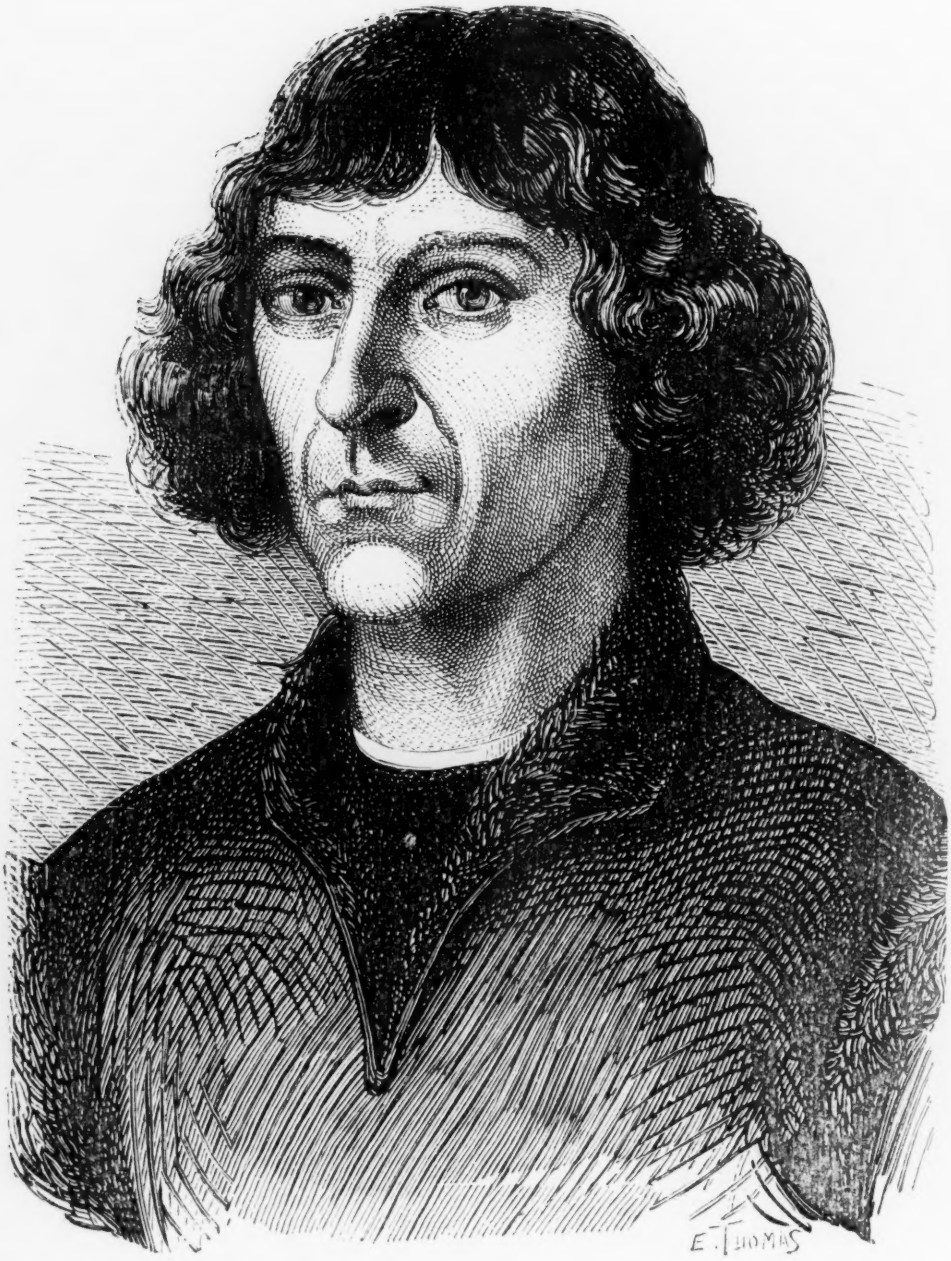
Following this, nearly half the book is devoted to a listing of 978 tropical storms known in American Atlantic waters since the time of Columbus, including maps of the tracks of all storms since 1901, and descriptions of the greater hurricanes. At the end, is a seven-page bibliography and a five-page index.

This is the second edition, the first having been published in 1938, just before the great New England hurricane. It is partly because of this storm and the evident need for wider knowledge of the nature of hurricanes and of the need for adequate precautions against them in areas where storms have not struck for decades that the new edition was brought out so soon. The main body of the text has been extended by about one page, to bring to date the part that radiosondes are playing (pp. 9–10), and to summarize losses of life and property in the twenty-five years 1917–1941 (p. 133). The losses of life are set at 4200 in the United States and in excess of 10,000 in the West Indian region, Central America and Mexico. Property losses in the United States in these twenty-five years seem to have been of the order of half a billion dollars, more than fifty per cent. of which was in the New England hurricane of 1938. An appendix of eight pages briefly summarizes the hurricanes of 1938–41, without, however, giving any references to detailed published discussions even of the meteorology of these storms, either here or in the bibliography, which includes no references to hurricane literature later than 1937. Minor defects in the first edition have unfortunately been mostly carried over into the second. For example, the wind map (Fig. 21), is credited to Bartholomew, the cartographer, rather than to Köppen, who compiled it. On p. 47 it is stated that hurricanes develop just south of the Isthmus of Panama, when Tehuantepec is apparently meant. On Fig. 40, Adjuntas, P. R., which the text, p. 70, states had 29.6 inches of rain in the hurricane of Sept. 13–14, 1898, is shown as less than 25 inches.

"Hurricanes" is an exciting book to read and it is valuable to keep for reference, especially if a hurricane threatens! Tannehill's treatment stands alone, as well it might, the author being chief of the Marine Division of the Weather Bureau and having had many years' experience as forecaster at Galveston, which after the greatest hurricane disaster in the history of the United States (in 1900) is now, "with its sturdily built buildings and its great seawall, . . . more strongly fortified against the tropical cyclone than any other city in the world."

CHARLES F. BROOKS

[1] *Hurricanes, Their Nature and History.* Ivan R. Tannehill. Second edition. Illustrated. x + 265 pp. $3.50. 1942. Princeton University Press.



NICOLAUS COPERNICUS, 1473–1543

THE PROGRESS OF SCIENCE

COPERNICUS AND THE HISTORY OF SCIENCE

THE life work of Copernicus culminated in his masterpiece, "The Revolution of the Heavenly Bodies." This astronomical publication performed a two-fold function in the History of Science: It undermined the old philosophical system of the world, which was earth centered and glorified man; it laid the foundation for a new scientific system of the physical universe, which enthroned nature as the final arbiter of natural law. The doctrine that the earth and other planets revolve about the sun replaced the old geocentric system and originated the inductive period which culminated in Newton's law of universal gravitation, accepted at that time as the greatest scientific generalization of the human mind.

The apparent motion of the heavenly bodies had attracted the attention of all primitive races—the daily rising and setting of the sun, the monthly waxing and waning of the moon, the periodic advance, turning point and recession of the planets along the zodiac, the annual heliacal rising and setting of the constellations marking the return of the seasons. The ancient royal astronomers of the practical Chinese observed the stars to determine the time for seed-time and harvest and to direct state affairs. Ancient Sumerians, Indians and Egyptians added to the recorded observations and determined the periods of the recurrences of celestial phenomena.

The Greek philosophers inherited the accumulated data of the ancients, and Plato proposed the problem of reducing celestial motions to mathematical law. Some observations were added and the adopted solution was an immovable earth at the center of the universe. The Pythagoreans proposed an imaginary central fire around which revolved the real bodies including the earth and an imaginary counter-earth. Aristarchus, the ancient Copernicus, advocated a system with the sun at the center; but Aristotle and others, including Hipparchus and Ptolemy, accepted the geocentric doctrine. Incorporated in the science, philosophy and religion of Europe, it survived the Dark Ages and played its part in the rise and decay of Scholasticism. Intrenched in the early universities of the Renaissance, several of which Copernicus attended, and upheld by the authority of the church, the geocentric doctrine appeared invulnerable.

It took indomnitable courage to propose a doctrine, patiently worked out through prolonged mathematical labor, which challenged the authority of the ages. But the mind of man was expanding. Printing presses multiplied and Columbus sailed beyond the known horizons. The great life work of Copernicus at this opportune time changed the scientific outlook of the world and shook the foundations of philosophy and religion.

It is said that Copernicus was accused by Kepler of interpreting Ptolemy, not nature. We agree with the first, but hesitate to accept the latter part of the accusation. It is true that Copernicus thoroughly understood all the details of the Ptolemaic system, even to the extent of applying the geometric method with modifications to explain his own heliocentric doctrine. We reject the insinuation, however, that Copernicus did not interpret nature. He failed to obtain a complete solution of the problem of motion of the heavenly bodies, but to use Melanchthon's figure, "He stopped the sun and set the earth in motion." Furthermore, the physical universe with its unnumbered stars was interpreted by him as a larger and grander system than previously conceived by the mind of man. This conception followed the absence of observed annual parallax of the stars due to their very great distance. He

correctly interpreted the puzzling loops in the apparent paths of a planet as a combination of the real motions of the planet and the earth. His heliocentric doctrine overthrew the Ptolemaic system which interpreted "nature as she seems, not as she is."

Following the basic work of Copernicus, Tycho Brahe made systematic observations of planetary motions using improved instruments and methods, thus providing more accurate data for the solution of the age-long problem. Galileo applied the telescope in astronomy,

THE COPERNICAN SYSTEM

challenged the authority of Aristotle and established fundamental principles in dynamics, the science of motion. Kepler abandoned the metaphysical idea of uniform circular motions and established his three empirical laws, based on the ellipse. Newton, standing on the shoulders of these men, invented the essential method of the infinitesimal calculus, introduced the necessary concepts in physics, including mass, and succeeded in formulating the law of gravitation, the first great physical synthesis, which rationalized the empirical laws and gave a scientific solution of Plato's problem.

The motion of the perihelion of Mercury's orbit defied Newtonian gravitation but satisfactorily obeys the broader generalization of relativity proposed by Einstein. On the foundation provided by Copernicus, a Pole, the superstructure was built by a Dane, an Italian, a German, an Englishman and a Jew, who is now an American by choice.

The work of Copernicus caused a revolution in science that dealt a severe blow to the smug anthropocentric ideas of the sixteenth century. Science, philosophy and religion had accorded man a position of self-imposed dignity at the center of a world of his own, created for his edification, real only as conceived by his transcendent mind. When the immovable terrestrial foundation was removed from the center and set spinning around the sun, not merely was the outmoded natural philosophy of Aristotle left behind, but the authoritarian rationalized principles in moral philosophy, metaphysics and theology—man-made systems—were also left without a firm foundation. The teleological explanation gradually gave way to a mechanistic interpretation of the universe, which was not favored by Newton himself, whose work completed the inductive period begun by Copernicus. The naïve realism which followed, attributed perhaps wrongly to the physical scientists, dropped the transcendentalism, but was inclined to hold to the universality of its so-called laws of nature. In the nineteenth century biology proved that "natural laws" are not immutable by demonstrating the variability of species. The new realism of the twentieth century, with data from the physical universe, based on the quantum, wave mechanics and Einstein's relativity, brings us again face to face with the motions of the heavenly bodies as a test of truth and reality. Thus four centuries after the death of Copernicus we build on the foundation he laid.

W. Carl Rufus

EXHIBITS OF INDIAN LIFE BEFORE COLUMBUS

With the opening of the west section of a new hall in the Field Museum of Natural History (Chicago), a section called "Indian America," an era of radically improved technique in anthropological exhibits has been inaugurated. Here the visitor will find to his delight that a few specimens with practically no labels, but with good lighting and a liberal use of gay colors harmoniously and tastefully blended, constitute irresistible displays. All previous ideas and methods of displaying materials have been discarded. Formerly, it was our wont to exhibit specimens—many baskets, hundreds of stone tools, rows of pots—with no attempt to give meaning to these objects. Just as a series of nonsense syllables do not make a poem or the words in a dictionary do not constitute a story, so did these exhibits make little sense to anyone. There are many museum curators who still cling to the notion that a drab case, full of spears or butterflies or rocks, is so tantalizingly attractive that the casual visitor will be compelled to look at the exhibit. Experience has proved that such exhibitions do not teach anything.

The scientific method, which includes observation as well as the recognition of realities, when applied to this antiquated notion of museum exhibits shows conclusively that the ordinary visitor will give no more than a hasty and bored glance at these "systematic" exhibits. For the most part they tell no story, have little meaning, are dull, forbidding and fatiguing, and have been responsible for the common phrase, "Dead as a museum." The most that may kindly be said about the older systematic exhibits is that they are really study collections stored in public halls and useful only to a handful of specialists.

The Department of Anthropology at the Field Museum has rejected these outworn methods and started to work out new methods of display which will teach the function and meaning of objects. The first practical application of these methods has been tried out in this hall which is to be devoted to Archaeology of the New World. The first section of the hall was opened January 25, 1943.

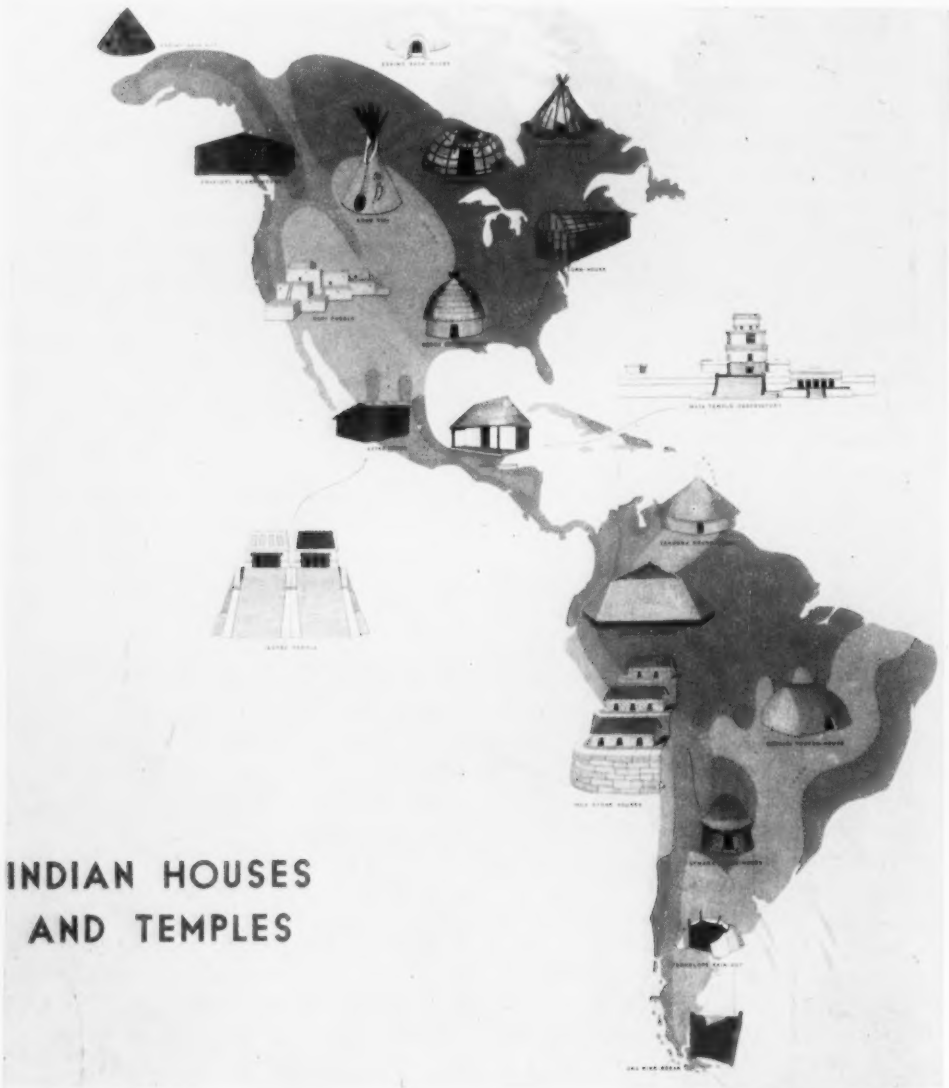
Synopsis of Early American Cultures

To set forth the archaeology of North, Central and South America in one hall may seem like a bold, almost impertinent, and impossible feat. Yet we are confident that it can be done. Of course, we shall attempt to present only the most essential facts concerning the history of the Indian civilizations, but this will be done in a comprehensive though necessarily synoptic fashion. The purpose of this entire hall will be to give the visitor a bird's-eye view of the ancient cultures and civilizations of the Americas. The accomplishments of the peoples of each large geographical area will be shown in relation to those of other areas. It is proposed to emphasize modes of life rather than specific traits and developments. The exhibits in the hall are designed to give in an integrated fashion a basic knowledge of New World archaeology to any interested visitor. From this hall the visitor can then go to the other Indian exhibits in the Museum with a framework of knowledge, understanding and depth of perception which will give him greater insight and pleasure. It is the avowed purpose to increase the knowledge, happiness and experience of every visitor by stimulating thought and feeling.

There will be three sections in this new hall, when it is completed: (1) "Indian America," the New World civilizations as the White Man found them. This section is now completed and was opened on January 25, 1943.

Field Museum of Natural History

MAYA NUMBERS, FREQUENTLY FOUND IN MAYA "FARMERS' ALMANACS"



Field Museum of Natural History

TYPES OF INDIAN HOUSES AND TEMPLES

AS THEY WERE BUILT IN DIFFERENT PARTS OF NORTH, CENTRAL AND SOUTH AMERICA.

(2) The New World civilizations as they were in the thousands of years preceding Columbus. This section will exhibit the main accomplishments of the Peruvians, Mayas, Aztecs and Pueblos, as well as those of the Indians of the Mississippi Valley and the rest of North America. It will also show the chronological order and the sequence of these civilizations from approximately the year 1492 back to the earliest evidence of man in the New World—or about

Field Museum of Natural History

CLOTHING OF THE INDIANS OF NORTH AND CENTRAL AMERICA

15,000 to 25,000 years ago. The task of presenting these subjects will be carried out by means of dioramas and a limited number of specimens tastefully arranged to illustrate use.

(3) Techniques: how stone, bone and metal tools, pottery, baskets and clothing were made and used; how archaeologists find, excavate and date ancient ruins; and, finally, how archaeologists collect and interpret information such as is assembled in Section 2.

In Section 1 are shown some of the fundamental characteristics of New World civilizations and cultures as they were at the time when the White Man came: that is, at the point where recorded history and archaeology (unwritten history) meet. It is axiomatic that to exist, every man must eat, clothe himself, erect some form of shelter, and make and use tools—even though all of these homely and fundamental tasks be performed either on a relatively simple plane or in a complex way. These aspects of Indian life are exhibited in this section, not with reference to one isolated area, but with reference to the entire New World. Such fundamentals can best be considered in this way.

The exhibits deal with a series of important culture traits arranged to show their forms and their spatial distribution over North, Central and South America. Specifically we take up the following subjects: (1) Where we obtain some of our knowledge concerning the customs of the Indians; (2) architecture (houses and temples); (3) travel and transport; (4) clothing; (5) decorative art; (6) economy—that is, agriculture, tobacco, hunting and fishing, seed and root gath-

Field Museum of Natural History

USE OF THE *BOLAS*

THE *bolas* (SPANISH FOR "BALLS") WAS USED BY THE NOMADIC INDIANS OF THE PATAGONIAN PLAINS TO CAPTURE THE GUANACO, A SPECIES OF WILD CAMEL, WHICH WAS THEIR CHIEF SOURCE OF FOOD. ONE BALL WAS HELD IN THE HAND AND THE WEAPON WAS WHIRLED ABOUT THE HEAD AND RELEASED IN THE DIRECTION OF THE ANIMAL. THE WHIRLING THRONGS CAUGHT ABOUT THE ANIMAL'S LEGS AND NECK, AND BROUGHT IT TO THE GROUND. THE INDIAN THEN KILLED IT WITH A CLUB.

ering; (7) distribution of types of basketry, pottery, weaving and textiles, and metal work; (8) a chart showing why some Indian civilizations are rated higher than others; and (9) writing.

These newly opened exhibits are really an example of the way archaeological knowledge is built up. The procedure which has proved most useful is that of working from the historically recorded known back into the past. The starting point for investigation is where recorded history—as left by conquerors, explorers and missionaries—and the unknown (prehistory) meet. This is the point whence archaeologists begin their "backward research." The visitor is shown the final and some of the greatest advances made by the Indians before the coming of the Whites. From this scene, one will (when the next section is ready) journey backward into prehistoric times and will obtain glimpses of what was happening in various New World areas, at say, A.D. 1200, 1100, 1000, 900, 800, and finally 20,000 B.C.

PAUL S. MARTIN

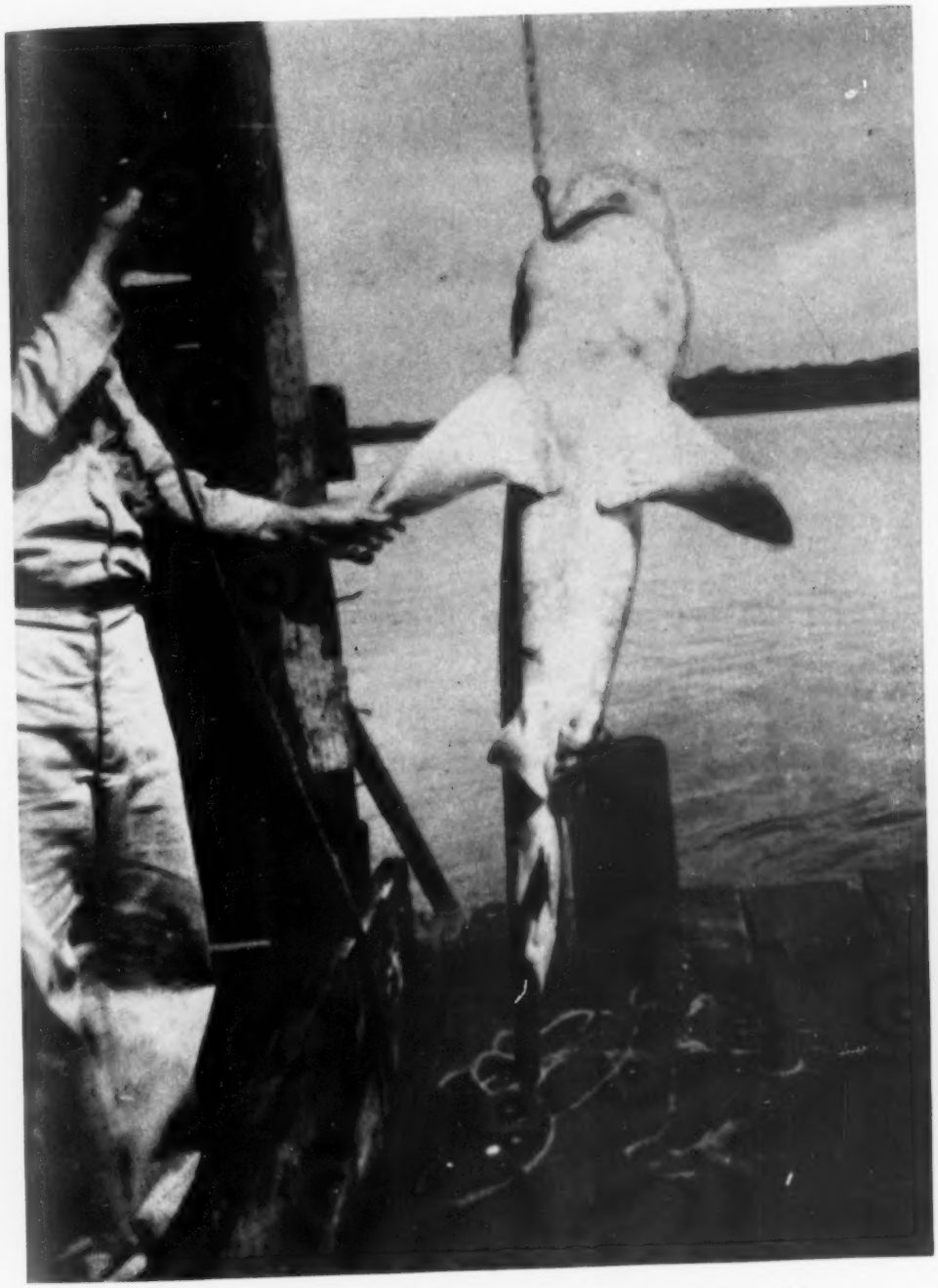
FRESH-WATER SHARKS OF NICARAGUA

HARVARD UNIVERSITY ichthyologists are jubilant over the arrival of the only known fresh-water shark in the world. He is *Carcharinus nicaraguensis*, caught after a series of tribulations, in the tepid waters of Lake Nicaragua in the Latin American republic. Although Harvard has not yet solved the problem of how the shark shook off his salt water habits, perhaps many thousands of years ago, and took to the fresh water of the lake, it has been proved, for the first time, that the creature came from the Atlantic rather than the Pacific side of Central America.

The weazened remains of the Nicaragua shark rest in the basement of the University Museum, an unappetizing sight for the layman but a choice morsel for those scientists who devote their lives to the study of rare fish.

Harvard's efforts to obtain a specimen of *Carcharinus nicaraguensis* started a year ago. Through the cooperation of the Carnegie Institution, which had archaeologists working near the lake, a shark was snagged out of its waters. With due ceremony, it was placed aboard a schooner, in a barrel of salt, for the first leg of shipment to Cambridge. A submarine without a sense of humor spotted the schooner and sank it. *Carcharinus nicaraguensis*, quite irretrievable, thus returned to the salty habitat of its ancestors and sank to the bottom with the ship.

Dr. Thomas Barbour, director of the University Museum, and Dr. Henry B.



ONLY SPECIES OF FRESH-WATER SHARK IN THE WORLD

Carcharinus nicaraguensis, WHICH HAS JUST BEEN RECEIVED AT THE UNIVERSITY MUSEUM AT HARVARD UNIVERSITY. IT WAS CAUGHT IN LAKE NICARAGUA IN LATIN AMERICA BY MAJOR CHARLES M. DUKE, AN AMERICAN ARMY ENGINEER.

Bigelow, professor of zoology, who finally identified "C.N." as of Atlantic origin, renewed their efforts to get a specimen to Cambridge. They had heard that Sweden, many years ago, obtained one, and they knew that a specimen which was on show in Washington in the gay '90's had disappeared. Unless it was being kept under cover *Carcharinus nicaraguensis* was not represented in this country, dead or alive.

An appeal was addressed to President Anastasio Somoza of Nicaragua. An ardent angler, the President went fishing several months ago and dragged not only one but three sharks out of the lake. Photographs of the event were taken and sent to Cambridge. Harvard fish experts took new heart. But facilities for shipping the sharks here were lacking, because of the war, and the President was left with nothing but pictures to show for his prowess.

Finally, last February, an American army engineer, Major Charles M. Duke, joined the Harvard hunt and caught the shark now in the University Museum. The creature, when taken out of the water, was about five feet long. The fresh-water sharks of the lake have been rumored to reach the length of ten feet. They have the nasty habits of their salt water relatives and are considered dangerous even by the Nicaraguan natives.

In the '70's, these fresh-water sharks were discovered. Theodore Gill, famous Smithsonian ichthyologist, obtained one and gave it the family name, in honor of Nicaragua.

However, according to Dr. Bigelow of Harvard's museum, this variety of shark was never compared with salt-water sharks to determine whether its original family habitat was the Atlantic or Pacific Ocean.

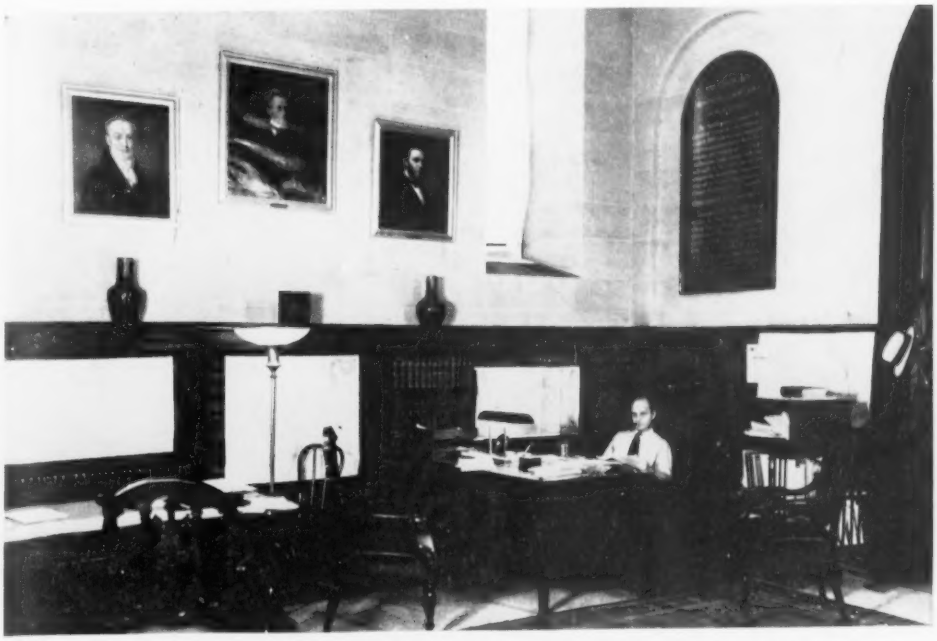
"It is apparently of Atlantic origin," said Dr. Bigelow. "When it got into the lake we can not say. It might have been centuries ago. How it got in is more of a mystery. A river, going down to the sea from the lake, has such steep descents and swift rapids that I don't believe a shark could swim up to the lake. The presence of these fish may be due to convulsions of nature, such as a volcanic eruption, which aeons ago changed the conformation of the land.

"Amazingly enough, the fresh-water shark has changed very little from the salt-water shark of the Atlantic coast of Nicaragua during its residence in the lake. The shape of the mouth and the relative position of the fins show the only differences." H. U.

THE ETHNOGEOGRAPHIC BOARD

THE armed forces and other government war agencies are constantly in need of securing rapidly authoritative detailed information upon regions in all parts of the world which are now, or may in the future, be of strategic importance. Yet no comprehensive means exists in the government for establishing direct contact with the best qualified individuals and groups, regardless of profession, to furnish such data. On the other hand many scholars and scientists possess the information the government needs, but are not always acquainted sufficiently with the government agencies to be able to place these data in the hands of the official who most needs them. The Ethnogeographic Board was established in June, 1942, as a clearing house through which the various government agencies and the scholars and the scientists of the country could be brought together more rapidly and effectively to solve questions relating to world regions.

The Ethnogeographic Board is sponsored by the National Research Council, the American Council of Learned Societies, the Social Science Research Council and the Smithsonian Institution. The last of these has graciously provided office space and facilities in the Smithsonian Institution Building and



DR. WM. DUNCAN STRONG, DIRECTOR OF THE ETHNOGEOGRAPHIC BOARD
SEATED AT HIS DESK IN THE OFFICE OF THE BOARD IN THE SMITHSONIAN INSTITUTION.

permitted several of the staff members to devote practically full time to assisting the Board in its work. Early this year generous grants from the Rockefeller Foundation and the Carnegie Corporation have insured the effective continuance of the Board's activities for many months to come.

Two conceptions are fundamental to the Board's activities. In the first place it is a non-governmental agency established in the name of the scientists and scholars of the country for the purpose of aiding the government. In the second place, because its primary interest lies in many regions of the world, it is interdisciplinary in scope, seeking to use the facilities and knowledge of the earth sciences, the biological sciences, the social sciences and the humanities, in so far as these relate to regions outside of the continental United States.

The Director of the Board is Dr. Wm. Duncan Strong, professor of anthropology, on leave from Columbia University. The membership of the Board was selected jointly by the four sponsoring organizations on the basis of the individuals' competence in their respective disciplines and their familiarity with major world regions. The present membership of the Board is as follows: Wendell C. Bennett, Carter Goodrich, John E. Graf, Mortimer Graves, Carl E. Guthe, Chairman, Robert B. Hall, Wilbur A. Sawyer and Douglas M. Whitaker.

Associated with Dr. Strong in carrying forward the activities of the Washington office is a group of individuals who have been appointed as need for their services has arisen. It is anticipated that additions to this group will be made as required.

By demonstrating the usefulness of the Board's facilities, Dr. Strong has established official liaison relations with the Army, the Navy, the Office of Strategic Services, and informal but equally effective relations with a large number of other government agencies, including the Board of Economic Warfare, the State Department, the Department of Agriculture, the Office of the Coordinator of Inter-American Affairs,

PORTRAITS OF THREE SECRETARIES OF THE SMITHSONIAN INSTITUTION
ON THE LEFT IS SAMUEL PIERPONT LANGLEY, A PHYSICIST AND ASTRONOMER WHO FIRST DEMONSTRATED THE PRACTICABILITY OF MECHANICAL FLIGHT; IN THE CENTER IS DR. CHARLES G. ABBOT, AN ASTROPHYSICIST WHOSE MAIN RESEARCH IS IN SOLAR RADIATION—THE PRESENT SECRETARY OF THE INSTITUTION; ON THE RIGHT IS CHARLES DOOLITTLE WALCOTT, A GEOLOGIST WHOSE WORK WAS DEVOTED MAINLY TO CAMBRIAN PALEONTOLOGY.

the Office of Foreign Rehabilitation and Relief Operations, and others.

The types of inquiries received from the several government agenices fall into four major classes. The first of these is for informal "spot" information, which can usually be secured within not more than one or two hours. The second is for data upon individuals or groups or upon some specific regional question which may require a day or two of searching. A third is for infomation which requires some compilation and study by qualified experts, resulting in a manuscript report which can usually be completed within a week or so. The fourth requires the organization of a project to be undertaken by an individual or organization which will result in a formal report at the end of several months. All but the first type of these requests are usually received as written directives from the proper government officials.

In order to meet the inquiries concerning competent personnel the Board has established a file arranged by areas containing detailed information about competent individuals who have visited particular regions. This includes their specific fields of interest, their experience in the field, and the nature of the data, including maps and photographs which they possess. In establishing these personnel lists the Board has drawn upon the lists prepared by various committees of the sponsoring organizations, the facilities of the National Roster of Scientific and Specialized Personnel, and the lists made available to it by some

government agencies and some civilian organizations.

In answering the inquiries from government agencies relating to conditions in particular regions, the Board uses the many facilities of the sponsoring organizations, and through them those of the divisions and affiliated societies with which the sponsors are associated. Dr. Strong's relations with many different government agencies also enable the Board to arrange for the exchange of pertinent information between government agencies as occasion arises.

Because of Dr. Strong's knowledge of the interests and activities of the government agencies, the Ethnogeographic Board is able to render a distinct service to the scholars and scientists of the country. It is in a position to place committees of scholarly organizations in touch with the appropriate officials of government agencies, and also to advise individual scientists and scholars visiting Washington concerning procedures they should follow in establishing proper government contacts. In addition, the Board has sponsored a series of conferences in Washington upon regional problems to which are invited scholars and scientists in government service, thereby bringing about exchanges of opinion among professional men working in various government agencies.

It must be recognized, of course, that the many government war agencies possess a variety of means of securing information upon strategic regions. Therefore the Ethnogeographic Board is not used by these agencies to secure routine information, but rather is called upon concerning subjects which the several agencies are unable to clarify through other channels available to them. Accordingly, the Board has expanded its activities in relation to the types of requests which have been received. These activities have been increasing in scope and expanding in terms of the regions covered. It is expected that the Board will continue to call upon additional sources of information as the demands made upon it by the Government agencies increase in scope.

The reception accorded the Ethnogeographic Board by the government agencies and the cooperation received from scholars and scientists and their organizations throughout the country have amply demonstrated that the Board is filling a definite need and performing a useful service during this time of emergency. The office of the Board is establishing a "back-log" of information and sources of information which will make its services cumulatively more valuable. For obvious reasons immediate war needs receive first consideration, but various projects concerning post-war problems are also being prosecuted. Inquiries and suggestions from individuals and organizations in the scholarly and scientific world are invited.

CARL E. GUTHE,
Chairman, Ethnogeographic Board

AN EXAMPLE OF FUSION OF SOIL BY AN ELECTRIC ARC

DURING a lightning flash the potential difference may be of the order of 1,000,000 volts, the current produced ranging from a few thousand to 100,000 amperes. This energy may be released in an interval ranging from .0002 second up to perhaps 1 second in a multiple discharge, when successive flashes occur along the same path. During severe thunderstorms in rugged regions, lightning frequently strikes at high points, sometimes fusing the rock. There are on record instances where lightning, striking into sandy formations, has produced long, branching, tubular fused structures, called fulgurites. These fulgurites are often several feet long but seldom more than two inches in diameter.

MASS PRODUCED BY FUSION OF TOP-SOIL BY AN ELECTRIC ARC

During a violent thunderstorm near Wooster, Ohio, on May 30, 1942, an interesting and spectacular thing happened. A three-phase, 60-cycle transmission line carrying 22,000 volts was struck by lightning. The field wire, about the diameter of a lead pencil, was severed at the insulator and one end dropped to the ground on the field below. The current continued to flow through the wet soil, and for a distance of 45 feet, where the wire touched the ground, a series of electric arcs was produced, developing tremendously high temperatures. The great heat produced and the annoying glare of the arcs made it difficult for linemen to get near the wire. The wire was severed at 12:18 P.M., but the location of the break was not discovered until 3 o'clock. During this interval, at the point of the arcs the soil was fused into molten masses of slag which were left lying parallel with the wire for a distance estimated at 45 feet. The molten masses cooled into round, elongate bodies, having the shape of the trunk of a tree, with branches extending out to a foot in distance and the ground was baked to a distance of a foot. A mass of fused material, 18 inches long and four inches in diameter, was removed and is shown in the photograph. Four fragile branches about an inch in diameter were broken off during the process of removal.

The material is glassy and very vesicular, showing that the soil was fused. The vesicles are explained by the steam that was formed from the water in the soil. Some of the vesicles are more than two inches in diameter and as much as five inches long, with a tendency to be hollow in their centers although the openings are not continuous like the interior of a tube.

The soil in this region is glacial in origin, containing a variety of rock material such as clay, quartz grains, fragments and particles of limestone and sandstone, iron oxide, humus, and occasional rocks classified as glacial erratics. It can reasonably be inferred that the unusual body produced by the electric current fusion of top-soil was formed in the same manner as fulgurites and possesses the same characteristics.

KARL VER STEEG